FOOD TECHNOLOGY

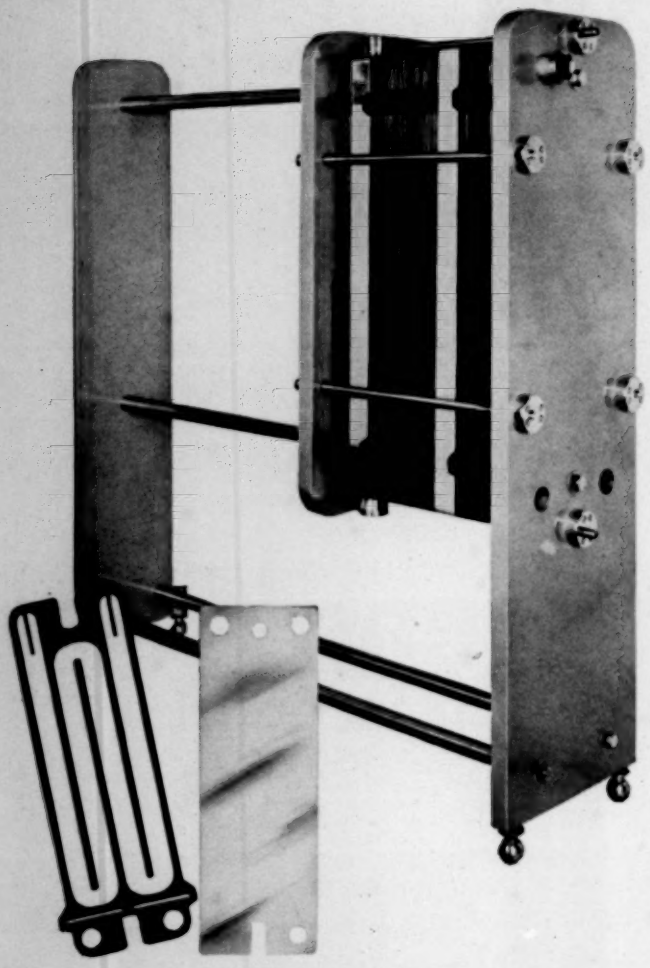
PUBLISHED BY THE INSTITUTE OF FOOD TECHNOLOGISTS

Volume IV, Number 8
August, 1950

UNIVERSITY OF MICHIGAN LIBRARIES

Something Really New... Pfaudler

"SANI-PLATE" FILM FLOW HEAT EXCHANGERS!



FEATURING ADVANCED SANITARY DESIGN

Pfaudler announces a plate heat exchanger with the same advanced sanitary design features that mark all Pfaudler equipment. Field tested for three years as the United unit, Pfaudler now brings it to you with improved features.

The Pfaudler "Sani-Plate" departs from conventional design through the elimination of plate corrugations and gaskets fastened to steel, both of which are possible sources of bacterial contamination. Pfaudler "Sani-Plates" are perfectly smooth, made of polished stainless steel. They are separated with sanitary divider seals which direct product and medium completely across the plate for fast heat exchange. Simplicity and sanitation keynote design.

Now dairies, *large and small*, can cool, heat or regenerate in a plate heat exchanger for greater economy—capacities from 1000 lbs. minimum to 20,000 lbs. per hour! Pfaudler HTST pasteurizers are equipped with accurate controls, pumps, holding tubes and balance tank, all built into the unit. For further information and prices, use form below.

TYPICAL SATISFIED USERS

Borden Company, Mfg. Division	Elgin, Illinois (3)
Seeley Dairy Company	Chicago, Illinois
Minnesota Creamery Company	St. Paul, Minnesota (2)
Furnas Ice Cream Company	Des Moines, Iowa
Western Condensing Co.	Eldorado Springs, Missouri
Dailey Pickle and Canning Co.	Saginaw, Michigan
Mendota Cheese Company	Mendota, Illinois
Lanes Jersey Dairy	El Paso, Texas
M. Stephens Company	Chicago, Illinois (2)
Eagle Dairy Products Co.	Detroit, Michigan (2)
Chocolate Products Company	Chicago, Illinois
Croswell Pickle Company	Croswell, Michigan
Morrocco Wine Company	New Brunswick, New Jersey
Stokes Dairy Farms	Franklin Lakes, New Jersey
U. S. Dept. of Agriculture	Albany, California
Snee Dairy Company	Pittsburgh, Pennsylvania

. . . and many, many others

EASY TO CLEAN— Smooth polished stainless steel plates are easy to clean. One-piece rigid sealers, coated with thermoplastic, are odorless, tasteless, heat resistant and sanitary. No crevices where rubber joins steel to worry about.

INEXPENSIVE TO INCREASE CAPACITY— Plates and sanitary sealers are easy to remove and insert, permitting adaption of any unit for different applications quickly.

BUILT FOR HIGH PRESSURES AND TEMPERATURES The design of this unit is such that pressures as high as 50 psi. are considered normal. Materials are approved for temperatures up to 250° F.

Pfaudler

THE PFAUDLER CO., ROCHESTER 3, NEW YORK

Engineers and Fabricators of Food Processing Equipment

GLASS LINED STEEL
Hastelloy Aluminum
Tantalum Carbon Steel
Solid or Clad Stainless Steel
Nickel Inconel Monel

The Pfaudler Co., Dept. FT-7 Rochester 3, N.Y.

Please send more information about the New Pfaudler Sani-Plate Film Flow Heater. Capacity required_____

Name_____

Company_____

Address_____

City_____ Zone_____ State_____

Food Technology Curricula

This is the third of a series of articles which are intended to elucidate the basic ideas that govern the curricula of our educational institutions in the field of food technology. The author or authors of each article belong to the staff of a Department of Food Technology which is actively training students. It is planned to include an article from each educational institution offering a curriculum in food technology. The article will describe the philosophy which guides the course of study and will describe the contents of the course. Included in the series later will be a report by the IFT Committee on Education and Curriculum, based upon the results of a questionnaire which was recently submitted to members of the IFT.

The Training of Food Technologists at the Massachusetts Institute of Technology

BERNARD E. PROCTOR

(Received for publication, May 17, 1950)

The fundamental philosophy relating to the training of food technologists at the Massachusetts Institute of Technology is to provide a basic curriculum that will enable its graduates to go into any food industry and utilize techniques or equipment of chemist, physicist, biologist, or engineer as need may demand. In contrast to courses of training designed to produce dairy technologists, cereal technologists, or specialists concerned with other individual types of food commodities, the food technology curriculum at the Massachusetts Institute of Technology has consistently placed emphasis on training to produce men skilled in the fundamental principles of the instruments and the methods by which *any* kind of food can be analyzed, modified, combined with other foods, processed, or controlled. The objective of such training has been to make the graduate more versatile and of greater value to himself and his future employers.

The major educational institutions in the United States that are interested in the teaching of food technology should devote their efforts to providing their students with a sufficient background of fundamental knowledge in this science to become key men in the food industries of the future. A distinction should be made between food technologists with four or more years of college training and food technicians who are less extensively trained. The food technologist and the food technician are not the same. The technician is able to carry out certain routine tests for which he has been specially trained. The technologist should be able to apply basic knowledge to evaluate and utilize the results of routine tests in a broader and deeper consideration of the problems demanding his skill and attention.

It would be unreasonable to expect any one person, in a college training period of only four years, to attain a complete scientific background and outstanding skill in all the fields pertinent to food technology. However, at the completion of his college training in food technology, the graduate should have acquired a basic knowledge on which specialized skill and professional experience can be rapidly built.

The object of the food technology curriculum at the Massachusetts Institute of Technology is to use the four undergraduate years to implant and develop in the student a broad understanding of the fundamental sciences and engineering principles utilized in food technology, to focus the efforts of the student on the interrelations and the applications of these fundamental sciences and engineering principles in a wide and generalized field of food processing, with less regard to specialized processes of food treatment.

The present curriculum in food technology at the Massachusetts Institute of Technology is the outcome of a program started in an informal manner some decades ago. At the start, the education of students going into food industries was directed in large part toward thorough training in chemistry and bacteriology. Subsequently there was a trend toward additional emphasis on training in engineering, unit operations, equipment, and management. In the years immediately following World War II, the trend has been toward more training in engineering, at the expense of training in biological subjects. The most recent changes have been the inclusion of physical chemistry and chemical engineering, which have necessitated abbreviation of previous bacteriology courses and dropping of physiology and anatomy, which formerly had been included in the curriculum.

An outline of the undergraduate courses in food technology given at the Massachusetts Institute of Technology as of 1950 and the sequence of these courses from year to year throughout the undergraduate period of study are presented in Table 1.

First Year. The first-year courses of all students are identical, irrespective of the students' special fields of interest. The courses comprise training in general chemistry (inorganic), physics (mechanics and heat), mathematics (calculus), English composition, engineering drawing, and descriptive geometry. These are considered fundamental to any training embracing scientific or engineering activities.

Second Year. After the first year, students diverge into their special fields. In food technology, the second year includes intensive courses in quantitative and qualitative chemistry, in physics (electricity and optics), and in mathematics (including differential equations as well as calculus). A course in general biology is given, especially in the biology of plants and in zoology, with

TABLE 1

Undergraduate Courses in Food Technology, Massachusetts Institute of Technology as of 1950

First Year	
Chemistry, General	Descriptive Geometry
Physics	Calculus
Engineering Drawing	Military Science
English Composition	Athletic Program
Quiz Hour (calculus, chemistry, physics)	
Second Year	
Qualitative Analysis	Calculus
Quantitative Analysis	Differential Equations
General Biology	History—Humanities
Physics	Military Science
Required During Summer	
Organic Chemistry	
Organic Preparations	
Third Year	
Physical Chemistry	Technology and Chemistry of Food Supplies
Physical Chemistry Laboratory	Industrial Microbiology
Colloidal Chemistry	Bacteriology
Introduction to Business Management	Economic Principles—Humanities
Elective Subjects	
Fourth Year	
Food Engineering	Technology of Food Products
Biochemistry	Chemical Engineering Food Applications
Chemistry of Nutrition	Thesis[a]
Humanities	

[a] The thesis involves more than 200 hours of study and original investigation with respect to some phase of food production and research.

emphasis on the physiological and economic aspects rather than the more common classical and taxonomic treatment of these subjects.

Summer Course. Two months in the summer following the second year must be devoted to the study of organic chemistry and the preparation and purification of simple organic compounds.

Third Year. In the third year, the student is given a thorough grounding in physical chemistry, a brief course in colloidal chemistry, a strong introductory (first-term) course in bacteriology, and a course (second-term) in industrial microbiology, that is, bacteriology as it relates to industries, especially foods and fermentations. The student also has a course in economic principles, an introductory course in business management, and one of a group of courses in the humanities, which may deal with psychology, labor relations, or industrial economics.

Specific attention is directed to foods in the third year. A course is given, extending through both terms, called the "Technology and Chemistry of Food Supplies." This course comprises lectures and laboratory work dealing with composition and analysis of foods, basic food processes in industry, plant procedures, and quality control. The student is required to visit, study, and submit reports on plant operations in a number of selected food fields. The solution of problems constitutes a definite part of this course also.

In the summer following the third year, the student usually works in a minor capacity as an employee of some food organization, to gain experience in various types of food operations. Such employment is encouraged, and arrangements for employment in seasonal food industries are made through staff contacts. A summer spent in some food manufacturing plant with opportunity to see problems first hand often results in marked changes in the viewpoints of these men when they return for their fourth year.

Fourth Year. In the fourth year the fundamental principles of chemical engineering operations as applied to the food industry are stressed in a separate course dealing with those aspects. Another course called "Food Engineering," given by staff members of the Department of Mechanical Engineering, relates to mechanical equipment, machine design, construction, materials, heat-transfer and refrigeration, and specialized mechanical equipment such as pumps and packaging machinery. An extended course in biochemistry includes food analysis, the physiological aspects of various foods in the process of digestion, and the activities and control of enzymes. A brief but exacting course in the chemistry of human and animal nutrition is also included.

The major work in foods during the fourth year, a course called the "Technology of Food Products," includes consideration of methods of food preservation and manufacture, such as canning, refrigeration, dehydration, and alteration and combination of various raw materials to produce finished products. This course includes an analysis of unit operations and processes employed, and consideration of the means by which they may be controlled. It is also concerned with fundamental procedures in food packaging and problems of deterioration of foods in storage. Included also are numerous trips to food manufacturing plants, which have been most cooperative in this area.

Two courses in the humanities are also included in the fourth year. English and the broadening courses in the humanities have not been stressed in this discussion, but these are considered essential. The ability to write clear, concise English is certainly a necessity for any technologist, and much attention is paid to this type of training.

Thesis. In his senior year, each student is expected to write a thesis on some original research problem, both to gain experience in the writing of reports and to provide concrete evidence of ability and proficiency. The actual experimental work, combined with the accumulation and analysis of experimental data, and the preparation of the thesis require that the student devote a minimum of over 200 hours to this particular project.

Five-Year Curriculum. In 1945, the Massachusetts Institute of Technology inaugurated a five-year curriculum in food technology leading simultaneously to the degrees of Bachelor of Science (awarded usually at the end of the four-year curriculum) and Master of Science in Food Technology. This five-year curriculum is restricted to a limited number of students who, upon application, are selected at the end of their first three years on the basis of exceptional performance. Outstanding men from other universities are also accepted at this point in their studies. In this five-year program, the courses of study are identical with those of the four-year program for the first four years, except for the thesis. For the five-year men the thesis is omitted in the fourth year and a course in production is substituted.

In June, at the completion of the fourth year, each of these men goes to work under special supervision in a selected food industry, which cooperates with the Insti-

tute's Department of Food Technology. His work in the food industry continues from June until the following February, when the second school term usually begins. During this period he is an employee of the food company and receives a nominal wage. Upon returning to the Institute, he continues his studies for two terms, at the successful completion of which he receives his two degrees.

The courses given in the fifth year are:

First Term	*Second Term*
Food Technology, Advanced	Food Technology, Advanced
Food Technology Seminar	Food Technology Seminar
Enzymology	Thesis
Electives	Electives

In the five-year curriculum, the student has a wide choice of electives in the various departments of the Institute, such as chemical engineering, physics, mechanical engineering, engineering administration, biology, and chemistry. His choice is guided but not restricted. He is allowed to make selections in the phases of food technology in which his interests lie. Included in the requirements is the writing of a thesis more than twice as comprehensive as that required for the B.S. degree.

The additional training and expense of the five-year curriculum are justifiable for capable men who plan to spend their future productive years in the field of food technology.

Doctorate. Further studies are necessary for men working for a doctorate. Their program is more specialized and advanced. It is dependent on their specific interests and whether their undergraduate background has been one largely in engineering, chemistry, or biology. It is becoming evident that food companies, even moderate sized organizations, expect their laboratory heads to hold doctors' degrees. This tendency cannot be disregarded. The training for the doctorate stresses the knowledge of past developments in a given field, relates to current events, and apprises of future events in the making. The institution offering graduate training must have an active group of research investigators on its staff, whose specific interests and zeal will serve to stimulate graduate students and help to develop future leaders in technical fields.

No one college course can prepare the food technologist to meet all the diverse technical, personal, and scientific requirements demanded by the fifty thousand food industries of the United States. A college course in food technology, however, should give the food technologist the requisite scientific background and the necessary knowledge of the instruments useful in his profession. With this preparation, the college graduate in food technology should be able, under the guidance of those in industry, to develop the special skills and acquire the information pertinent to the particular industry in which he is located.

This consideration of the training of food technologists has necessarily been concerned with those phases with which the writer is most familiar. Other educational institutions have set up their curricula on the basis of their experience and the market for which their product is best adapted. This curriculum at the Massachusetts Institute of Technology has been developed over a considerable span of years and is the result of numerous changes indicated by experience. It will undoubtedly be modified further in the future. Progressive instruction in any field dependent on the developments of modern sciences must be in an almost constant state of flux. Certainly teaching relating to food technology must be subject to changes to keep abreast of the rapid current of developments and the anticipated future progress of the food industries.

Any industrious young man who has absorbed even a part of training of this nature for a period of four years, regardless of the institution he attends or the professors and the subjects they teach, should have no difficulty in finding a suitable field for his services in some one of the thousands of widely diversified food industries, to the mutual advantage of all concerned.

Beginnings of the History of the Institute of Food Technologists

The history of an organization, like the history of an individual does not begin with the moment of its emergence as a new entity into a world of other living units. Rather it is the result of many factors of heredity and physical activities extending backward through the years. Such is the prenatal history of the Institute of Food Technologists.

Unknowingly many domestic operations in food preservation had long used the principles of science. The application of scientific principles to the *commercial* production of foods had also *begun* many years ago as we recall from the work of Appert. Canning of many types of products, manufacture of condensed milk, refrigerated shipment and storage of foods had all come into use, but lacked the precise control which the trained Technologist was later to supply.

The work of Prescott and Underwood at the Massachuetts Institute of Technology and of Russell at Wisconsin had put sterilization of foods on the road to assured success. Brewing was advanced by pure yeast culture. Milk supplies were made safe by pasteurization, and other dairy products improved by the use of pure cultures.

These were typical of the steps that had been taken in food manufacture, and there were many others. It was the good fortune of the writer to be encouraged to arrange a series of courses in what was first called Industrial Biology with instruction on canning of vege-

tables, fruit and fish; making of jams and jellies, brewing and other fermentations such as cider, wine, vinegar, and work on milk, butter and cheese, in the Department of Biology at the Massachusetts Institute of Technology at Cambridge, Mass., in the first decade of the 20th century, and to establish a commercial laboratory in 1905 for the special investigation of food problems. Possibly other laboratories were also in operation for similar purposes. The first course of study for training in these aspects of food work were thus set up at M.I.T. 10 years previous to World War I. That war, because of the demands for foods in enormous quantities for the millions of soldiers, greatly increased the interest and the actual demand for manufactured or treated foods, and brought to the front the process of commercial dehydration, to which the Food Division of the Surgeon General's Office of the Army, the Food Administration under Herbert Hoover, and the Bureau of Chemistry of the Department of Agriculture all contributed research and ideas, and many colleges and other laboratories gave cooperation.

So far as the writer knows the course in Food Technology at M. I. T. was the first to be established in an educational institution. The term, Food Technology, which was coined to describe its general nature, was thought to be original, but it has since been made clear that the late Tom Rector had used these words in describing, in a circular for distribution to prospective customers, the work under his charge in the Cushman Industrial Laboratory in Washington.

It is clear that from many men and various laboratories ideas were trending in one direction and would eventually come into approximate focus. For this to take place there was needed an opportunity for exchange of thoughts and experiences, a common meeting-ground for friendly cooperative discussion, and the practical banishment of alleged secrecy on matters and processes that could not remain mysterious and secret to the observant and logically-thinking man with broad technical training.

While the foregoing paragraphs are not an integral part of the actual history of the Institute of Food Technologists, it is hoped that they suggest some of the significant influences that led to its establishment.

Immediately after World War I a more highly organized program in Food Technology was put in effect at M. I. T. and within five or six years a dozen or more capable men had been graduated from it and were following this work as a professional field.

Interest had also been growing elsewhere:—at the Department of Agriculture and in universities and agricultural colleges, notably in California, Illinois, Massachusetts, Wisconsin and Iowa.

It was soon recognized that the *technical* aspects of commercial food manufacture required not chemistry alone, nor bacteriology alone, but a union of these with fundamentals of engineering, and with plant observation to give the stock-in-trade and "know-how" that make the special skill of the Food Technologist.

By 1935 it seemed to us at M. I. T. that the time was near at hand when a conference of those who had specialized in the various aspects of food manufacturing or in the study of its underlying problems should be profitable. Teachers of the more advanced essential subjects, as researchers in special problems; microbiologists; biochemists; plant operators and designers of food handling machinery all could give valuable information which should be co-ordinated. We therefore began to initiate plans for such a conference, and were heartily supported in the idea by such men as Burton, Blanck, Newton, Cameron, Tressler, the late Lewis Waters and Bitting and many others. Of our own group Emerson, Proctor, and the younger men, Bates, Highlands and others supplied ideas, technical skill, and enthusiasm. An orderly plan was prepared, with papers to be presented by invited speakers.

When the proposal was placed before President Karl T. Compton, with a request for financial support by M. I. T., a cordial reception was secured. To his question, "How many Food Technologists do you estimate would attend such a conference?" the reply was that certainly as many as 50 or 60 and possibly as many as a hundred would make an effort to attend.

To make such a conference a really significant occasion it was agreed that it should not be merely regional in character but should have national scope, and to assure even greater breadth and importance, it seemed desirable to invite distinguished leaders in Canada, Great Britain, Germany, France and possibly other countries to attend. The outcome of the negotiations was highly satisfactory. An appropriation of $1500 was granted by the Institute's Corporation, this money to be used in helping to pay transportation expenses for invited men from foreign countries, and for some other necessary expenses of the meeting. The date for the conference was set for June 30 to July 2, 1937, thus giving ample time for correspondence and preparation. The official meeting was to be held in the main lecture hall of M. I. T. in Cambridge. The Institute itself thus served as host. Invitations brought favorable replies from Dr. Rudolph Plank of Karlsruhe, M. Piettre from Paris, Dr. Thomas Moran from the Cambridge Low Temperature Research Station in England and Dr. Roy from the Fisheries Research Station at Aberdeen. Canadian experts also responded cordially to invitations extended to them.

With the arrival of the date stated, for which a number of local committees had made adequate preparation, it was found that the conference was far more successful than had been anticipated . Instead of the 60 promised, over 500 people were in attendance. While the majority came from nearby areas, many states and several Canadian provinces were represented, and foreign visitors came not only from England, Scotland, Germany and France, but also from Norway and Belgium. The report of the conference with full reports of the papers presented, was published by *Food Research* as a special double number in the volume for 1937.

At this meeting no special consideration was given to the formation of an association or organized body although such a desirability at some future time was intimated in the presiding officer's remarks in welcoming the conference to the Institute.

The interest evoked by this conference was widespread and permanent. Comment was cordial and pleasantly reminiscent as those who had been present met at other conventions such as those of the American Chemical Society or the Society of American Bacteriologists and the American Public Health Association. The success of the initial venture had been so marked that within a year we planned to hold another conference at M. I. T. in 1939, although it was impossible to secure a subsidy for inviting foreign guest speakers. Notification of this intention was given to those who had participated in the first conference.

As a result of this information a small group met at the Experiment Station at Geneva, N. Y. in August, 1938, to consider possible plans for an organization, and again, with some addition in numbers in New York City a few months later (January 16, 1939). Memoranda relating to these meetings are found in the preface to the official Secretary's Reports of this I. F. T.

The second food conference was held at M. I. T. in June, 1939, with a three-day program and many important papers. Dr. B. E. Proctor was Chairman of the Program Committee. The interest and attendance at the second conference were as great as at the previous one, and we are told that there was much corridor discussion regarding organization and a session was held by an interested group late in the evening preceding the last day of the meeting, at which a preliminary constitution was developed as a means of crystallizing the aims and purposes of an organization, and the general qualifications of presumptive members. As a last matter for discussion before the adjournment of the conference on the final day, Dr. F. C. Blanck, who was presiding at this session, presented the general plans for organization and asked for a vote as to whether it should be formed. Receiving an enthusiastic response, and an indication of desire to join such a scientific body, the group so voting proceeded to accept the temporary constitution, to elect officers and the necessary committees to perfect the organization. So I. F. T. was born, and those present and accepting the conditions became *founder* members. Thus I. F. T. had many fathers.

The minutes of this organization meeting were admirably prepared by Dr. George J. Hucker who was elected to the office of secretary, and these very properly form the first chapter of his careful reports of the affairs of the Institute.

The first regular meeting of the Institute of Food Technologists was a great gathering, splendidly planned by local members, held at the Morrison Hotel in Chicago in 1940, the decennial of which we are now celebrating.

Our organization has become one of the important national societies in the scientific and technological field.

From small beginnings it has spread across the continent. From 22 founder members it has grown to an influential body with more than 3000 members, including foreign members in Central and South Americas, England, Holland, Germany, France, and the Scandinavian Countries in Europe, and in Australia, New Zealand and India.

It soon became evident that it was desirable to have regional branches or sections, and it is gratifying to record that there are now 16 such groups with more to follow. These, in order of establishment, are: Chicago with its great group and the distinction of having established the Appert Medal to be awarded annually by the Institute; Northern California, with its headquarters at San Francisco; Northeast, including most of New England with Boston as headquarters; Southern California, comprising the area dominated by Los Angeles; St. Louis and the Central Mississippi Valley; New York City; Western New York; Florida; The Great Lakes Section, with Detroit as its centre; Philadelphia; Puget Sound (Seattle as its capital); Maryland with Baltimore as centre; Ames, covering central and western Iowa; Mohawk Valley; Oregon, with Corvallis as its headquarters; Ohio Valley, centering around Cincinnati. This year at least two more have been authorized.

Since the 1939 Boston Conference the meetings have been held in Chicago (1940), Pittsburgh (1941), Minneapolis (1942), St. Louis (1943), Chicago (1944), Buffalo (1946), Boston (1947), Philadelphia (1948), San Francisco (1949) and Chicago (1950). A regional meeting was held at Rochester in 1945, but, on account of the war, was not a national conference.

The members of I. F. T. have reason to be very proud of its growth and its remarkable spirit.

It is notable especially for the warm friendliness that pervades its membership, and for the complete lack of petty sectional jealousies or cliques in any part of its organization. This has made it a strong and united body.

It is still young, even in comparison with other American organizations such as the Society of American Bacteriologists, or the American Public Health Association or the American Chemical Society.

It will prosper and endure as long as it renders a useful service to the food industry and visualizes, and works to meet, the needs of the whole people of our land; as long as it keeps the faith and holds to the aims with which it was begun. One can safely predict that so long as it does this it will be an institution great in its usefulness and in the spirit of true democracy.

SAMUEL C. PRESCOTT.

Flavor Profiles—A New Approach to Flavor Problems

S. E. CAIRNCROSS AND L. B. SJÖSTRÖM
Arthur D. Little, Inc., Cambridge, Massachusetts

(Received for publication, July 25, 1949)

The FLAVOR PROFILE presents a descriptive analysis of flavor expressing in common language terms the characteristic notes of both aroma and flavor, their order of appearance and intensities, and the amplitudes of total aroma and total flavor. The method enables a panel to evaluate the small differences which occur in the usual steps of flavor improvement. The concept furnishes insight to the philosophy of seasoning.

Introduction

The Flavor Profile represents a method of flavor analysis which makes it possible to indicate degrees of difference between samples on the basis of the intensity of individual character notes, the degree of blending and the overall amplitude. In the study of flavor improvement, laboratory panels often operate on the basis of preference. Secondarily, descriptive terms are used to indicate points of difference, but the interpretation of such observations as a guide to product improvement is usually difficult, especially in a prolonged series and in a series where small differences exist. In reviewing the efforts of the flavor group in these laboratories, in this direction, as well as those of others, it is apparent that this type of approach makes progress by minor degrees of improvement difficult and at times appears to lead in circles. The need has been felt for a more objective method of judging products which does not depend upon personal preference and which integrates the points of difference in such a way that products can be judged separately as well as in groups.

Sensory studies of the effect of monosodium glutamate on food flavor sharply focused attention on the inadequacy of any known method of expressing the phenomenon of the blending of flavor. Similarly, this work brought a great deal of attention to bear on the mechanism of seasoning, particularly with respect to the augmentation of certain character notes and the suppression of others. In the course of this work, a philosophy of seasoning has been developed which attempts to describe the general mechanism of the seasoning and flavoring of foods. In order to be able to analyze and describe the complex effects of various seasoning agents, it was decided to formalize a method of expression and description which was being used by the panels in a general way. This complete description of aromatic and flavor characteristics has been given the name of "Flavor Profile." The "Flavor Profile," which is a sort of flavor spectrum, may be expressed in either diagrammatic or tabular form. In the latter case it resembles a system of grading with a semiquantitative indication of the variation in the principal character notes. While the system has not yet been developed into a fully quantitative procedure, whenever necessary, measurement of the degree of intensity of any one factor can readily be reduced to quantitative evaluation by the use of outside standards. In any given series of products being examined for the first time, it is customary to use a rather complete tabular description, but eventually it is possible to concentrate upon only the principal points. Saltiness, sweetness and certain aromatic character notes may be judged individually, and by matching samples with outside standards these can be given fairly reproducible quantitative ratings.

It is the authors' belief that this method is the most flexible and adaptable method at present available for the operation of small research panels, particularly as a guide to flavor improvement studies. This procedure has been found useful in work on such diversified materials as: frozen fruits, dairy products, chewing gum, vitamin tablets, coffee, rum, beer, and soft drinks. In all of these products it is possible for a small panel to render descriptive analyses which are readily readable, understood and applied by both production and management. Although the method is still in a formative phase of development, it is felt that there should be no further delay in presenting it to other workers in the field who might wish to experiment with its applications.

In this presentation of the Flavor Profile it is desirable to stress three basic considerations of panel operation: training of panel members, development of descriptive terms and interpretation of results.

Training

Frequently it is common practice in flavor development work to expend much effort in attacking a problem and then to squeeze the evaluation panels into a crowded schedule, drafting panel members from occupations that they may consider more important. In flavor work at the Arthur D. Little, Inc. laboratories equal weight is given to the developmental and evaluation procedure, emphasizing scheduling and adequate time for panel sessions. This promotes full concentration, fosters interest and avoids the viewpoint that panel sessions are merely interruptions of regular work.

Since flavor analyses are no different from other laboratory analyses in requiring time for developing technique, persons who are to become members of a flavor panel are allowed ample opportunity to learn the fundamentals of taste testing. They sit in on panel sessions and are introduced to the ramifications of many flavor problems, in course acquiring the necessary experience and confidence. Likewise, every panel member is alloted time to become acquainted with each new flavor problem under consideration. He is encouraged to study the material by himself and later compare findings with fellow members. At the end of this acquaintance period all panel members together in seminar fashion prepare the Flavor Profile for the material which they have studied.

Terminology of Qualitative Aspects

Since each material possesses flavor and aroma characteristics which in type and intensity distinguish it from any other material, great emphasis is therefore given to exact descriptive terminology. The objective should be to use terms that most nearly characterize each component note.

The establishment of descriptive terminology in each flavor study begins when the panel members individually examine the material. While principal attention is given to aroma and flavor, other sensory phenomena may also be observed. In these laboratories aroma is defined as the odor impressions perceived in the nose by sniffing; for example, burnt, fragrant, pungent, sharp, and acidic. Taste is used to refer only to the basic factors perceived in the mouth: sweet, sour, salty, and bitter. Flavor or flavor by mouth includes those impressions received when the substance is taken into the mouth: the basic taste factors, odor, and feeling sensations, and often aftereffects.

It is customary to use associative terms such as "eggy," "rubbery," "cabbage-like" and "skunky" for the naturally-occurring odors due to sulfides and organic sulfur compounds. However, direct association with a definite chemical is attempted whenever possible; for example, phenylacetic acid has been the reference odor for a principal aromatic note in both beer and honey. An attempt is made to analyze the more important factors specifically, for instance, in the case of astringency, location of the effect is cited, as dry mouth, cheek puckering, tongue coating, and tooth roughing.

Useful descriptive terminology for a given product can usually be established after several panel sessions. The principal components of aroma and flavor that have been noted during the preliminary study are introduced and checked at round table discussions during which all panel members come to understand the meaning of each descriptive term, and adopt common terminology. It is understood that the panel be fairly homogeneous as to personality and training in order to encourage complete freedom of expression during all discussions. Every effort is made to establish the ideal conditions for round table discussion, avoiding pressure and domination.

While determining the nature of the principal components of flavor and odor, the tasters endeavor to establish the order of appearance and intensities of the individual notes as well as the overall amplitude of aroma and flavor. As will be shown later, the order of appearance of flavor notes in beer begins with salt, sweet, sour, and fruity.

Quantitative Aspects

Intensity of individual character notes is judged initially by an arbitrary scale based upon the recognition threshold, using the following designations: not detectable, just detectable, slightly strong, moderately strong, and strong.

Amplitude is regarded as the summation of all intensities and is applied to the overall impression of aroma body (total aroma) and flavor body (total flavor). In the case of a series, the sample having the least body is arbitrarily given unit amplitude, and the remainder rated accordingly.

To summarize, the Flavor Profile presents a descriptive analysis of flavor expressing in common language terms the characteristic notes of both aroma and flavor, their order of appearance and intensities, and the amplitudes of total aroma and flavor.

From this tabulation a response sheet is prepared which is intentionally simple, for elaborate rating sheets have been found to divert the attention of the analyst and complicate interpretation of results.

Figure 1 shows the response sheet developed for beer by the Flavor Profile method during an experimental program centering on beer flavor. A sheet like this is presented to each panel member who individually examines the sample at hand and records his findings. First he checks the amplitude of aroma and then studies

EXAMINATIONS OF BEER

Test No._____ Date_____ Signature_____

Aroma	Intensity	Amplitude
Hop Fragrance		
Estery		
Fruity		
Yeast		
Sour		
Malt		
Hop Resin		
Phenylacetic Acid		
Gassy (Illuminating)		
Skunk		
Others		

Flavor By Mouth	Intensity	Amplitude
Salt		
Sweet		
Sour		
Fruity		
Bitter		
Yeast		
Malt		
Phenylacetic Acid		
Skunk		
Metallic		
Astringent (Dry Throat)		
Others		

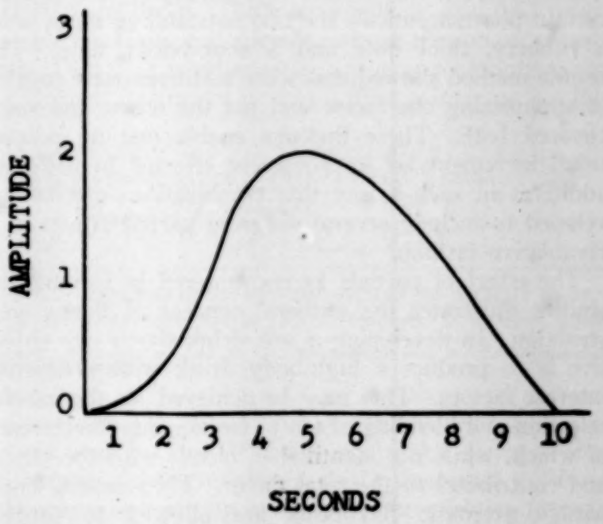


FIG. 1.

FIG. 1. Response sheet developed for the examination of beer.

aroma, looking for component notes indicated on the left of the sheet, and records their intensities in the parallel column in the middle. Other notes perceived can be recorded. Similarly he studies the flavor by mouth. Frequently in a flavor problem it is necessary to follow one characteristic intensively. For example, at the bottom of the test sheet there is plotted a curve which indicates the amplitude of flavor with respect to its duration. In beer and soft drinks as well, the rate at which maximum intensity is reached and rate of disappearance of total flavor apparently are important factors in product appeal.

Interpretation of Results

Upon completion of the individual examinations the findings are discussed in open panel, one person in the group acting as moderator and recorder. This discussion at the end of the closed panel is a unique feature of the Flavor Profile method, stimulating panel members to increase their acuteness and reliability, also fostering interest and self-confidence. Here, the moderator resolves differences existing as to the intensity of notes by resubmission of samples. Thus, a single composite Flavor Profile is obtained.

To determine the effect of an experimental modification of the sample, it is only necessary to compare its composite profile with that of the original sample.

With regard to size of panel, we have used groups of six to ten people and find that six is a practical panel for most purposes. The panels at the Flavor Laboratories of Arthur D. Little, Inc. are generally made up of chemists, but there is no reason why any intelligent non-technical group could not operate according to the same procedure, using descriptive terms common to their own experience.

Application of Flavor Profiles

In general, studies of flavor and aroma may be classified as corrective, formulative and analytical. The Flavor Profile method has been found particularly valuable in steering a program of flavor correction for foods and pharmaceuticals. For example, in exploring certain pharmaceuticals the two outstanding notes were a rubbery, thiol note and a sour-yeasty note. The profile method showed that some additives were capable of suppressing one factor and not the other, and some covered both. These findings enable one to indicate small increments of improvement effected by different additives in such a way that combinations can be developed to include several different partial effects in a cumulative fashion.

The effect of partials as encountered in formulation studies illustrates the authors' concept of flavor construction. In developing a soft drink flavor one objective is to produce a high-body drink with distinctive interest factors. This may be achieved by the careful selection and blending of ten to twenty ingredients each of which, while not identifiable, blends with the others and contributes to the total flavor. Then several compatible aromatic flavorants are allowed to project beyond the flavor body, adding interest, identity and character.

If one were to attempt to diagram the flavor using the Flavor Profile, a semi-circle of fairly large amplitude could represent the complex flavor body, and beyond would project the several outstanding notes. The majority of the ingredients would be at near-threshold level where they are not readily identifiable. Each by itself would be of little consequence in producing character, but by the addition of many partials an interesting and blended complex is built.

Figure 2 is a diagram of the profiles for both the aroma and the flavor of a carbonated beverage, the amplitudes being represented by the areas of the semi-circles. Thresholds are indicated by the perimeters of the semi-circles, and the individual notes perceived are

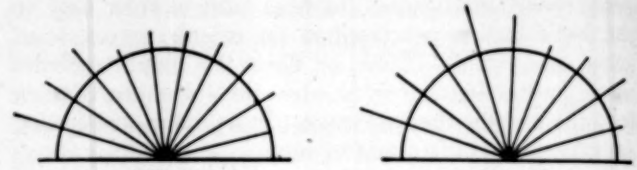


FIG. 2. Diagrammatic representation of the aroma and flavor profiles of a carbonated beverage.

designated by the solid lines that originate at the center. Some of the lines reach just to the perimeter. These notes are just at recognition level. The distance to which the other lines extend beyond the threshold border indicates detectable intensity of the notes they represent.

Not all of the formula ingredients of the beverage are identifiable, for the majority go to make up the blended body; however, it is probable that several are represented by one line. For example, in the aroma diagram, fragrance, as one of the perceptible notes, might be attributable to unrecognizable quantities of several different aromatics.

For the past three years these laboratories have been studying the effect of monosodium glutamate on a variety of foods. Certain of the typical seasoning properties of this salt (increase of blending and increased ampitude) are shown in Figure 3, which is the diagrammatic flavor profile for boiled, seasoned, fresh summer squash with and without 0.5 percent added monosodium glutamate.

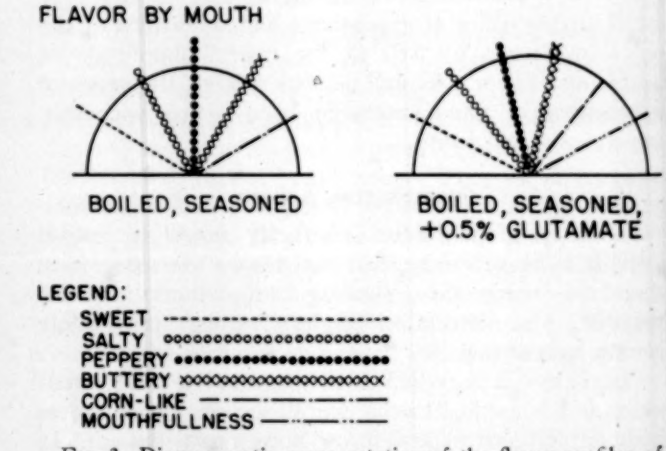


FIG. 3. Diagrammatic representation of the flavor profiles of seasoned summer squash.

The analytical panel found that first sweetness was perceptible in the boiled squash, seasoned with 0.5 percent salt, 0.05 percent pepper and 1 percent butter. After sweetness they tasted salt, a moderate amount of pepper and butter, and finally the squash itself which was found to resemble sweet corn. In the sample containing the added glutamate, seasoned and tasted at the same time, the outstanding quality was the blended character of the component notes, which is indicated by the augmented size of the semi-circle and the reduction of the outstanding notes. The order of perception of the flavor components was not altered but another factor, mouthfullness, was added.

Diagrammatic representations such as these profile drawings are useful in gaining the understanding of persons not versed in flavor techniques, for they are visual summaries and express fundamental concepts of flavor. These together with the tabular data sheets are valuable in providing management groups with a greater understanding of their own flavor problems and of the alternatives presented by research and production.

Inherent in any successful system of seasoning and flavoring is the building of an interesting complex of flavor. This is accomplished by the increase of blending, the building of greater amplitude, and the addition of interest factors. Such an approach allows for suppression of undesirable notes and augmentation of the desirable ones. This concept supplies a working scheme and philosophy to be followed in all problems of flavoring and seasoning. The Flavor Profile method is a means of indicating degrees of success in the development and control of optimum flavor.

Measuring the Firmness of Red Tart Cherries[a]

R. T. WHITTENBERGER
Eastern Regional Research Laboratory,[b] Philadelphia 18, Pennsylvania

AND

R. E. MARSHALL
Michigan Agricultural Experiment Station, East Lansing, Michigan

(Received for publication, May 17, 1950)

To determine the firmness of a sample of fresh red cherries, each of 20 cherries is compressed for 10 seconds between two flat surfaces by a force of approximately 300 grams. The results are expressed as average percent compression. The test is useful for measuring changes in firmness caused by bruising, cooling, soaking, and other treatments.

It is commonly considered that soaking red tart cherries in cold water preliminary to commercial processing increases their firmness. The extent of the increase and the effect of various factors on firmness are, however, not adequately known, since observations on firmness usually have been purely subjective. During recent studies on processing red cherries, the need for accurate data on firmness became apparent, and the method described below for measuring firmness was devised. The method involves compressing the whole fresh fruit by a pressure tester developed at Michigan State College,[c] and is somewhat similar to the methods employed by Verner *(4)*, Haller et al. *(2)*, and Rose et al. *(3)*, with other fruits. Comparable results on compression of cherries may be obtained by using a modified Delaware jelly-strength tester *(1)* as a pressure tester. Most of the results obtained by the method will be published in detail in subsequent papers.

Apparatus

The essential features of the pressure tester are a stage on which the cherry is placed, and two flat-surfaced discs about 2 cm. in diameter between which the cherry is compressed (Figure 1). One of the discs (A) moves forward across the stage, while the second (B) remains fixed. The force acting on disc (A) originates from three coil springs, whose tension is adjustable. Disc (A) is released by a trigger mechanism, and its forward movement is shown by a pointer on a millimeter scale. The initial force exerted by disc (A) varies almost linearly from about 200 grams at a spring setting of 2.5 cm. (characteristic of this instrument) to about 700 grams at a setting of 7.0 cm. The effective force at an instrument setting of 3.5 cm. decreases about 15 percent as disc (A) advances 5 mm.

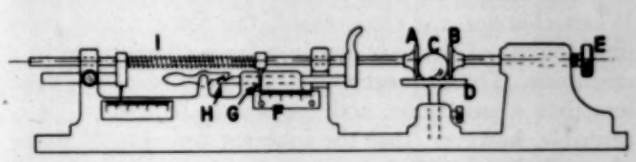


FIG. 1. Diagram of the essential parts of the pressure tester.
A. Disc (A), active. B. Disc (B). C. Specimen. D. Platform, adjustable. E. Screw adjustment for disc B. F. Millimeter scale. G. Pointer showing movement of disc A. H. Release for disc A. I. Compression spring, adjustable.

[a] Report of a study made under the Research and Marketing Act of 1946.

[b] One of the laboratories of the Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, United States Department of Agriculture.

[c] The details of the pressure tester, which is adjustable for use with a wide variety of fruit and vegetable tissues, will be published by G. J. Bouyoucos and R. E. Marshall.

Procedure

For determining the firmness of a lot of cherries, 20 fruits are taken at random, after the lot has been culled, and tested individually. The cherry (minus its stem) is placed on the stage with its stem end down and is oriented so that in its widest dimension it lightly touches disc (A). This orientation permits the compression of the maximum amount of flesh. Disc (B) is brought into contact with the side of the cherry opposite disc (A) by means of a screw adjustment. The maximum diameter of the cherry is determined by measuring with calipers the distance between the two discs. The initial force of disc (A) is adjusted to about 300 grams (instrument setting of 3.5 cm.). Next, disc (A) is released, and after approximately 10 seconds the amount of compression of the cherry is estimated to the closest one-tenth of a millimeter from the millimeter scale.

The data on the maximum diameters and on the compression of the 20 cherries each are averaged. From these two averages, the average percent compression of the cherries is calculated.

Discussion

It was necessary to evaluate the effects of several factors before arriving at a satisfactory procedure for measuring firmness. After measurement of cherries which varied widely in size, maturity, and extent of bruising, it was concluded that a force of 300 grams was near the optimum for covering the wide range in firmness. Forces moderately greater than 300 grams tended to mask small differences in firmness by compressing all specimens to approximately the same extent, whereas forces less than 300 grams did not yield a sufficiently high degree of compression in some specimens. The force was permitted to act for 10 seconds. In periods less than 10 seconds, the extent of compression was insufficient and the accuracy of reading from the millimeter scale was decreased, owing to the too rapid movement of the pointer.

The size of the cherry made a slight difference in the compression values, the largest cherries having the lowest values. For example, the largest 63 cherries (average diameter 20.9 mm.) from 9 different lots were compressed an average of 23.7 percent, whereas the smallest 63 cherries (average diameter 18.8 mm.) were compressed an average of 25.1 percent. Perhaps this result is associated with a shortcoming in the method. When cherries are compressed, the force acting on a unit volume of tissue is less in a large cherry than in a small one. Thus a large cherry tends to be compressed less than a small one, and appears to be firmer. It is probable, however, that the inherent firmness of tissue of small cherries is as great as or greater than that of large cherries.

Immature cherries were somewhat firmer than mature or over-mature cherries, and the firmness of all cherries varied inversely with the extent of their bruising and with the temperature. The test thus provides an objective means for determining the extent of bruising of cherries similar in size and maturity. Lowering the temperature from 21° to 1° C. increased the firmness of the cherries significantly (Table 1). The firmness of unsoaked cherries held at 1° C. increased steadily with time over a period of 12 days.

TABLE 1

Representative Data on the Compression of Montmorency Cherries

Treatment [d]	Average Diameter, mm.	Compression, Percent	Standard Error
Carefully picked; not bruised; not soaked			
1. Stored 2 hours at 21° C., tested at 21° C.	20.2	23.4	0.529
2. Stored 2 hours at 10° C., tested at 10° C.	19.9	21.5	0.560
3. Stored 2 hours at 1° C., tested at 1° C.	20.3	20.7	0.368
Difference required for significance at 5 percent level		1.4	
Commercially picked; bruised; tested at 27° C.			
4. Not soaked	19.1	28.0	0.718
5. Soaked 6 hours at 14° C.	19.3	27.4	0.633
6. Soaked 24 hours at 14° C.	19.4	23.8	0.414
Difference required for significance at 5 percent level		1.7	

[d] 20 cherries were used for each treatment.

The reliability of the test is indicated by the statistically treated data of Table 1. Usually the testing of 20 cherries from each lot (which required about 15 minutes) was adequate for revealing differences in firmness which would be of practical significance. However, if greater accuracy is desired, as is often the case in experimental studies, more than 20 cherries from each lot may be tested. Carefully picked and handled cherries were of fairly uniform firmness, and the standard error of measuring their percent compression was relatively low. For example, the difference in percent compression required for significance at the 5 percent level was 1.4 percent for the treatments outlined in Table 1. A greater difference (1.7 percent), however, was required for significance in commercially picked cherries (Table 1), owing principally to unequal bruising.

LITERATURE CITED

1. Baker, G. L. Improved Delaware jelly-strength tester. *Fruit Products J.*, **17**, 329 (1938).
2. Haller, M. H., Harding, P. L., and Rose, D. H. The interrelation of firmness, dry weight, and respiration in strawberries. *Proc. Amer. Soc. Hort. Sci.*, **29**, 330 (1932).
3. Rose, D. H., Haller, M. H., and Harding, P. L. Relation of temperature of fruit to firmness in strawberries. *Proc. Amer. Soc. Hort. Sci.*, **31**, 429 (1934).
4. Verner, L. Experiments with a new type of pressure tester on certain stone fruits. *Proc. Amer. Soc. Hort. Sci.*, **27**, 57 (1930).

Studies on Meat I.[a,b]
The Biochemistry of Beef as Related to Tenderness

S. A. HUSAINI, F. E. DEATHERAGE, L. E. KUNKLE AND H. N. DRAUDT

Institute of Nutrition and Food Technology, The Ohio Agricultural Experiment Station, The Ohio State University, Columbus, Ohio

(Received for publication, May 29, 1950)

Classical tests of nitrogen fractionation show no significant correlation with tenderness of beef. Alkali-insoluble protein reflecting connective tissue shows an excellent negative correlation. Marbling is of less significance than connective tissue as related to tenderness of beef.

Meat is the foundation of the American diet, and more livestock production is being urged upon the farmer. The consumer has very definite ideas on what makes a good piece of meat in terms of tenderness, juiciness, and flavor. Cost of meat is also uppermost in his mind. Much work has been done in the production of meat animals; also many studies have been done on meat. Relatively few are the studies which integrate the interest of the producer and the consumer. This has been recognized by many at the University and Experiment Station who also appreciate an unique opportunity provided by their combined facilities. At the same time it is realized that the answers to consumer desires in quality as well as to animal production problems rest fundamentally in the biochemistry, nutrition, physiology and production management of the meat animals. For many studies in these fields large numbers of animals must be used. The Meats Laboratory of the Animal Husbandry Department at the University distributes most of the meat for the dormitories, dining halls and hospitals of this large University while at the same time this laboratory provides slaughtering and meat processing facilities for courses in Animal Husbandry. With such facilities it is possible to sample large numbers of carcasses without suffering the prohibitive economic losses which have hindered much effective meat research. This paper is the first of a proposed series wherein animal production research will be integrated with consumer desires. In other words it is hoped that complete studies will be made taking the meat animals from birth to the table and thereby accumulate data which may permit closer scrutiny of values to the producer, packer and consumer alike.

For meat to be satisfactory it must be tender and flavorful. If either of these are inferior meat is unsatisfactory irrespective of all other factors. Perhaps of these two desired qualities tenderness is the more important and also lends itself to closer and more reproducible measurement. Accordingly one of the first problems is to interpret tenderness in fundamental concepts if possible.

Many important contributions have been made to our current knowledge of tenderness in meat and it is impossible to review them here, even though many of these have given information upon which this study rests. It is well established that the manner of cooking, the particular muscle or muscles used, and the post-mortem age all affect tenderness. Furthermore, the potential tenderness varies in animals and muscles. The Warner-Bratzler tenderness testing device has been used extensively in meat. The use of carefully set up taste panels permits the reproducible measurement of tenderness and hence permits critical study of this quality.

Deatherage and Rieman *(4)* in an extensive study showed the value and reproducibility in panel testing by six judges of broiled short-horn steaks as a measure of tenderness of meat. Their data indicated a wide variation in initial tenderness at 4 days, in tenderness after accelerated aging at 20° C. (68° F.), and in changes in tenderness. Also there was some indication that at least two factors were involved in tenderness. Deatherage and Harsham *(3)* studied the relation of tenderness with post-mortem age at 33-35° F. (0.5-2.0° C.) and found that in a group of 12 carcasses tenderness increased until 17 days post mortem after which no great changes occurred until 31 days. This gave further evidence of at least two factors involved in tenderness. The work to be reported here represents an exploratory study to try to determine at least one of these factors.

Twenty carcasses of wide variation in grade, age, and sex were sampled by excising one short loin from each carcass. The short loins were aged at 3.0° C. (38° F.) for 14 days and examined for tenderness, moisture, intra-muscular fat (marbling), pH, inorganic phosphate, lactate, total nitrogen, non-protein nitrogen, trichloracetic acid soluble nitrogen, and alkali-insoluble protein.

Fourteen days aging at 38° F. was selected as the time for carrying out these studies to correspond with the plateau in the tenderness-time curve of Deatherage and Harsham *(3)*. In this way it is hoped to eliminate the possibility that the rapidly changing tenderness of earlier post-morten ages would tend to obscure definite relationships.

Methods

Sampling: After squaring the anterior end of the short loin, a 2½ inch section of the loin was taken for chemical analysis followed by four 1 inch steaks for tenderness determination. The portion taken for laboratory study was trimmed in such a manner as to include only the meat corresponding to the edible lean portion consumed in the tenderness determination by the taste panel. This trimmed portion was ground four times through a 5/32 inch plate on a Kitchen-Aid grinder.

[a] Presented before the Tenth Annual I. F. T. Convention, Chicago, Illinois, May 22, 1950.

[b] *Studies of Meat II. Observations on Relations of Biochemical Factors to Changes in Tenderness* will be published in the September issue.

This ground meat was thoroughly mixed and used for chemical determinations.

Tenderness: Tenderness was determined in duplicate by the method described by Deatherage and Reiman *(4)* and is reported as the average value.

Moisture: Samples of meat weighing approximately 2 grams were dried for six hours at 104° C. (219° F.).

Fat: The acid-ether gravimetric method of Schmid *(11)* was used with slight modifications. Approximately five gram samples were used.

pH: A Beckman Model G pH Meter was used on a slurry of ground meat and distilled water.

Inorganic Phosphate: The method of Fiske and Subbarow *(5)* was used.

Lactic Acid: The procedure of Barker and Summerson *(2)* was followed.

Total Nitrogen: The Kjeldahl - Gunning - Arnold method as described by Winton *(13)* was used on sampes weighing approximately one gram.

Non-protein nitrogen: 70.0 grams of meat and 630 grams of water were mixed in a Waring blendor for 7 minutes, 100 ml. of this slurry was mixed with an equal volume of 10% $ZnSO_4 \cdot 7H_2O$ and then with 100 ml. of 0.5 N NaOH according to the method of Somogyi *(12)*. After filtering nitrogen was determined on 100 ml. of the filtrate by the method for total nitrogen above.

Trichloracetic acid soluble nitrogen: According to Hiller and Van Slyke *(6)* less than 5% concentration of trichloracetic acid precipitates only proteins and does not precipitate partially digested proteins. 50 ml. of the meat slurry prepared for non-protein nitrogen was mixed with 50 ml. of 5% trichloracetic acid and the mixture was shaken intermittently for 20 minutes and filtered. Nitrogen was determined on 50 ml. of the filtrate by the method of total nitrogen.

Coagulable nitrogen: The method of the Association of Official Agricultural Chemists *(1)* was used.

Alkali Insoluble Protein: The methods for determining collagen and elastin are rather involved and do not lend themselves to running large numbers of samples. Since both of these connective tissues are insoluble in dilute alkali while almost all other proteins of meat are soluble a procedure was developed to determine the proteins insoluble in 0.1 N sodium hydroxide as an index of the amount of connective tissue. The procedure developed is based on the method of Lowry, Gilligan and Katersky *(8)* for the estimation of collagen and elastin.

Fifty grams of meat and 40, 45 or 50 ml. of distilled water were blended together for 6 minutes in a Waring blendor. At intervals during this time the sides of the blendor cup and cover were scraped with a spatula and the material collected was added to the bulk of the mixture so as to keep the pasty mass as homogeneous as possible.

Six to eight grams of the slurry was accurately weighed into 50 ml. tared centrifuge tubes. 0.1 N sodium hydroxide was added to the 40 ml. mark and the meat alkali mixture was stirred with a small glass rod and allowed to stand 15-24 hours at 33°-35° C. The time is not critical but the temperature should be sufficiently high to prevent solidification of the fat. The materials in tubes were stirred again and then centrifuged. The supernatant liquid was removed by suction so as not to disturb the precipitate and discarded. The solid material sticking to the tube walls was washed down using 0.1 N sodium hydroxide and a policeman. Alkali was added with mixing to the 40 ml. mark and the mixture was allowed to stand with occasional stirring for an additional 12 hours. After centrifugation the supernatant liquid was discarded as before and the residue was washed with 40 ml. of water, stirred and centrifuged. The wash water was discarded and the washing repeated with 40 ml. of water. At this stage this material was neutral to phenolphthalein.

The residue was washed with 40 ml. of a mixture of equal parts of alcohol and ether using a policeman and mixing as before. After centrifugation the residue was washed with 40 ml. of ether centrifuged and ether discarded. The outsides of the tubes were cleaned with water or ether-alcohol mixture and dried for 4 hours in an air oven at 104° C. (219° F.). After cooling in a dessicator the alkali-insoluble protein was weighed directly. This method can be improved; however, in triplicate determinations the standard deviations were approximately ten percent of the mean value and served the purposes of this investigation.

All determinations were done in duplicate or triplicate and the values reported are the mean values. In order to maintain a reasonable working schedule 4 animals were studied at weekly intervals.

Results and Discussion

Since the primary purpose of this study was to correlate biochemical data with tenderness only those results which seemed to show some definite relationship will be reported in detail.

Carcasses were selected which showed wide variation in market grade. For purposes of attaching a numerical value to these grades the following carcass scores were given in terms of U. S. Grades: High Choice 15; Choice 14; Low Choice 13; High Good 12; Good 11; Low Good 10; High Commercial 9; Commercial 8; Low Commercial 7; High Utility 6; Utility 5; Low Utility 4; Cutter 3; Canner 2. Furthermore these carcasses represented wide variation in age, management and sex and unfortunately the history of each carcass was not known.

In Table 1 the main body of data is given in ascending order of tenderness. The animal number indicates the order in which they were studied.

On inspection of these data it is quite apparent that there is a very close relation between alkali-insoluble protein and tenderness at 14 days post mortem. This, of course, verifies the more or less common thinking that connective tissue is a major factor in tenderness; furthermore this confirms the reports of Lehman *(7)*; Mitchell, et al. *(10)* and Mackintosh, et al. *(9)*. The very high correlation of —0.87 indicates that this protein fraction is one factor directly responsible for toughness, the opposite of tenderness in meat. Deatherage and Harsham *(3)* indicated that at least two major factors are responsible. Since in this study tenderness was measured after 14 days aging the major changes in tenderness had taken place; consequently factors con-

TABLE 1

No.	Sex	Tenderness	Carcass Score	Alkali-Insoluble Protein %		Intra-Muscular Fat %	Moisture	pH	Nitrogen Partition in Percent Fat and Moisture Free			
				Wet Basis	Fat and Moisture Free				Total N	CCl_3COOH Soluble	Non-Protein	Water Sol. and Heat Coaguable
12	Cow	4.50	5	0.325	1.39	3.61	72.99	5.50	14.68	1.83	1.02	1.36
3	Heifer	4.50	8	0.324	1.43	4.12	73.28	5.59	15.60	1.75	1.08	1.35
16	Heifer	5.83	8	0.313	1.29	4.28	71.50	5.40	14.76	1.87	1.00	1.97
17	Steer	5.92	7	0.309	1.41	1.21	76.81	6.50	16.12	2.09	1.63	....
2	Steer	6.25	11	0.282	1.29	5.92	72.26	5.60	14.98	1.74	1.10	1.59
18	Bull	6.33	5	0.309	1.28	4.09	71.80	5.46	14.78	1.82	1.12	1.87
11	Steer	6.42	11	0.300	1.27	3.26	73.02	5.49	15.27	1.96	1.24	1.91
14	Steer	6.75	8	0.269	1.14	3.45	72.93	5.45	14.97	1.99	1.14	1.94
19	Cow	6.92	5	0.262	1.07	3.05	72.42	5.58	14.97	3.34	1.86	3.61
1	Cow	7.16	7	0.201	0.919	11.69	66.43	5.52	14.91	1.85	1.11	1.14
20	Heifer	7.25	11	0.199	0.882	6.58	70.86	5.45	15.40	3.09	1.64	3.54
15	Cow	7.33	11	0.191	0.832	6.88	70.15	5.49	15.22	1.95	1.10	1.87
5	Steer	7.50	12	0.194	0.850	7.78	69.29	5.42	14.93	1.94	1.22	1.80
6	Steer	7.83	12	0.191	0.805	4.18	72.12	5.38	14.84	1.88	1.18	1.67
13	Heifer	8.08	11	0.198	0.867	6.77	70.40	5.39	15.38	2.02	1.13	1.73
10	Steer	8.33	8	0.202	0.814	4.39	70.85	5.45	14.71	1.79	1.01	1.48
8	Steer	8.50	12	0.173	0.711	4.99	70.66	5.38	14.63	1.97	1.23	1.62
4	Steer	8.57	14	0.191	0.911	12.09	66.96	5.59	15.29	2.11	1.32	1.51
9	Heiferette	8.75	13	0.074	0.295	5.39	70.73	5.50	14.68	1.89	1.11	1.51
7	Steer	8.75	12	0.169	0.736	7.60	69.43	5.38	15.59	2.09	1.28	1.74
Correlation coefficient with tenderness			+0.66	—0.88	—0.87	+0.47	....	....	....	....	....	....

With 18 degrees of freedom correlation coefficients at the 1% and 5% levels are 0.56 and 0.44 respectively.

tributing to rapid changes in tenderness were eliminated here.

If a plot is made of alkali-insoluble protein versus tenderness, a sigmoid curve results where the sharp slope and inflection occur in the tenderness level 6-7. In this tenderness range it has previously been shown *(4)* that the standard deviations of tenderness measurements are minimal. The full significance of the relation between these two findings is no tunderstood but it is felt that there is some connection.

In these and other studies data have been accumulated which substantiate in detail the report of Deatherage and Reiman *(4)* concerning the reproducibility and the relation of standard deviations of tenderness scores and tenderness. In fact the test panel used in these studies showed somewhat greater reproducibility. In duplicate tenderness determinations the distribution of standard deviations over the tenderness scale are given in Table 2.

TABLE 2

Composite data on 63 duplicate tests showing distribution of the standard deviations of tenderness scores with respect to tenderness level.

Tenderness Level	No. of Duplicate Tests	Average Tenderness	Standard Deviations
8-9	10	8.37	0.405
7-8	13	7.51	0.459
6-7	14	6.60	0.354
5-6	10	5.62	0.421
4-5	4	4.42	0.682
3-4	12	3.42	0.333

The method reported here for determining alkali-insoluble protein is not recommended as yet for a substitute for tenderness determinations. The study reported here was done in summer where the mean laboratory temperature was always greater than 30° C. (86° F.) and the alkali digestion was done at room temperature. Using this same method in the winter during another study to be reported later where the mean laboratory temperature was 21° C. (70° F.) it was discovered that somewhat irregular and higher values were obtained apparently due to troubles related to solidification of fat. It is intended to continue work to improve the method so as to enhance its value.

An excellent correlation +0.66 was obtained between tenderness and carcass grade in this group of great variation in market grade. This, of course, was to be expected in a study of this sort. It should also be pointed out that a lower value for the correlation coefficient results if only steers and heifers are included.

A significant but rather poor correlation of +0.47 was obtained between tenderness and intramuscular fat (marbling). This seems a rather poor relation considering the emphasis placed on this attribute of beef. This value compared with the 0.66 for carcass grade indicates perhaps that other grading factors have a more important bearing on tenderness.

As can be inferred from Table 1 a lot of work was done on nitrogen fractionation without finding any significant relation of total nitrogen, non-protein nitrogen, trichloracetic acid soluble nitrogen or heat coagulable water soluble nitrogen to tenderness. The only conclusion is that these classical methods are of no importance in determining subtle protein differences related apparently to tenderness.

Similarly no correlation was observed between lactic acid and inorganic phosphate and tenderness. The values obtained for these biochemical factors were within the normally expected limits. With the exception of animal No. 17, a dark cutter with a pH of 6.50, the values for lactic ran between 0.81% and 1.18% and for inorganic phosphorus between 0.085% and 0.120%. For No. 17 lactic acid was 0.39% and inorganic phosphorus was 0.164%. These values are on the wet basis.

No relationship with tenderness was observed for pH and moisture.

Summary

A group of 20 animals was studied which represented wide variations in market grades. These animals were dressed at local packing plants, and no information regarding age, breed or history of the animals was available. Using short loins from the carcasses of these

animals after 14 days' aging at 3.5° C. (38° F.) tenderness was evaluated on broiled short loin steaks and at the same time moisture, pH, fat, total nitrogen, non-protein nitrogen, trichloracetic acid soluble nitrogen, water soluble heat coagulable nitrogen, and the alkali insoluble proteins were determined. From these data the following conclusions were drawn:

There was a very close negative correlation between tenderness scores and the alkali-insoluble proteins.

No correlation was found between tenderness scores and total nitrogen, trichloracetic acid soluble nitrogen, non-protein nitrogen or heat coagulable nitrogen.

A low but significant correlation existed between the intramuscular fat ("marbling") and tenderness.

A very significant correlation between carcass grades and tenderness values was also obtained.

No relation was observed between tenderness and pH, moisture, lactic acid or inorganic phosphate.

Acknowledgment

The authors wish to express their gratitude to Professor Inez Prudent and the Department of Home Economics whose close cooperation made this study possible. The assistance of Professors L. H. Burgwald, T. V. Armstrong, and Vern Cahill is gratefully acknowledged.

LITERATURE CITED

1. Association of Official Agricultural Chemists. Official and Tentative Methods of Analysis. 6th Ed., Washington, D. C. Association of Official Agricultural Chemists, p. 428. 1945.
2. Barker, S. B., and Summerson, William H. The colorimetric determination of lactic acid in biological material. *J. Biol. Chem.*, **138**, 535 (1941).
3. Deatherage, F. E., and Harsham, Albert. Relation of tenderness of beef to aging time at 33-35° F. Food Research, **12**, 164 (1947).
4. Deatherage, F. E., and Reiman, Walter. Measurement of beef tenderness and tenderization of beef by Tenderay process. *Food Research*, **11**, 525 (1946).
5. Fiske, C. H., and Subbarow, Y. The colorimetric determination of phosphorus. *J. Biol. Chem.*, **66**, 375 (1924).
6. Hiller, H., and Van Slyke, D. D. A study of certain protein precipitants. *J. Biol. Chem.*, **53**, 253 (1922).
7. Lehmann, K. B. Studien über die Zahigkeit des Fleisches und ihre Ursschen. *Arch. fur Hygiene*, **63**, 134 (1907).
8. Lowry, O. H., Gilligan, D. R., and Katersky, E. M. Determination of collagen and elastin in tissue. *J. Biol. Chem.*, **139**, 795 (1941).
9. Mackintosh, D. L., Hall, J. L., and Vail, G. E. Some observations pertaining to tenderness of meat. Proc. Am. Soc. Animal Production, 29th annual meeting, p. 285 (1936).
10. Mitchell, H. H., Hamilton, T. S., and Haines, W. T. Some factors affecting the connective tissue content of beef muscles. *J. Nutrition*, **1**, 165 (1928).
11. Schmid, W. Bestimmung des Fettgehaltes in Milch, Rahm u. dergl. *Z. Anal. Chem.*, **27**, 464 (1888).
12. Somogyi, M. The nitrogenous substances in zinc hydroxide filtrates from human blood. *J. Biol. Chem.*, **87**, 339 (1930).
13. Winton, A. L., and Winton, K. B. The Analysis of Foods. New York. John Wiley and Sons, Inc. pp. 42-47 (1947).

The Effect of Temperature on the Bacterial Infection of Shell Eggs[a]

J. WOLK, E. H. McNALLY, AND N. H. SPICKNALL

Bureau of Animal Industry, U.S.D.A., Agricultural Research Center, Beltsville, Md.[b]

(Received for publication, May 29, 1950)

Examination of the entire contents of shell eggs showed that about 12 percent of fresh eggs (less than 7 hours old) contain bacteria. The rate of infection in eggs from the same source held at 90 to 95 percent humidity varied at the holding temperatures of 41° F., 77° F., and 95° F. It is concluded that the penetration and survival of bacteria in shell eggs are favored by elevated temperatures; of the temperatures used, the maximum activity of bacteria occurred at 77° F. (25° C.).

The effect of temperature on the keeping quality of eggs has interested investigators for many years. Many of these workers have checked quality by standard candling procedures, some have used visible fungal growth as evidence of spoilage, and a few have attempted to determine the actual bacterial infection of eggs held under various conditions. The conditions under which eggs are kept in the store and even in the home may play an important part in the final quality of the eggs. The present study was undertaken to determine the effect of temperature on the bacterial infection of eggs held at uniform humidity for a relatively short time.

Methods

It is difficult, if not impossible, to make a completely satisfactory bacteriological examination of shell eggs. Differences in technic can be, and often are, responsible for marked variances in results. Such variables as manner of sterilization of the shell, size of sample and method of sampling, and nature of the culture medium used, must be considered when analyzing results.

Most methods for cleansing the shell call for immersion in $HgCl_2$ (1-500 to 1-1000), with or without previous scrubbing with soap and water, and subsequent rinsing in alcohol and/or ether.

Pennington *(4)* scrubbed eggs in clean water and soaked them in bichloride (1-1000) for a few minutes. Each was washed with sterile water, and enough shell was removed from one end with sterile instruments to allow the introduction of a pipette. Then the membrane was broken and about 2 cc. of white pipetted off and weighed. After the rest of the white was removed, about 2 cc. of the yolk was pipetted into a flask con-

[a] Presented before the Tenth Annual I. F. T. Convention, Chicago, Illinois, May 22, 1950.

[b] Report of a study made under the Research and Marketing Act of 1946.

taining broken glass, and weighed, as the white had been. Equal portions from three eggs were mixed and dilutions made. She used nutrient agar, litmus lactose agar, and nutrient gelatin as media. Maurer *(3)* cleaned eggs with soap and water, immersed them in 1-500 $HgCl_2$, and rinsed them in alcohol and ether. A small hole was then made in the small end of each, and the other end heated to expel white and yolk in two portions each into 100 cc. of broth. Subcultures were made into agar plates. Stiles and Bates *(8)* took no special precautions in examining eggs. They simply broke the eggs over the edge of a Petri dish and placed them in sterile dishes. Then 1 cc. portions were pipetted into American Public Health Association medium. Eggs showing no bacteria in 1 cc. were considered bacteriologically sterile. The high percentage of infected eggs they obtained probably reflects their failure to sterilize the shells. Hadley and Caldwell *(1)* reported that Poppe (1910) and Cao (1908) treated eggs in much the same way that Maurer did. However, they punctured both ends of the egg and allowed the white to run into a flask of broth from one end, and the yolk into another flask from the other end. After incubation, agar plates were poured from dilutions of the egg-broth mixtures. Hadley and Caldwell used a similar technic, but tried streaking directly on agar; later they mixed the yolk only with small amounts of broth, transferred to new broth tubes and plated out positive tubes. The Standard Methods for the Examination of Dairy Products *(7)* calls for scrubbing and draining each egg, immersing it in 70 percent alcohol for 10 minutes, and flaming. Then the egg contents are expelled into a sterile, wide-mouthed jar through a 0.5 inch hole in the small end of the egg. The egg contents are thoroughly shaken or beaten, and 11 grams are weighed out directly into a 99 cc. dilution bottle. Suitable dilutions are plated out.

The problem of how much of the egg to use as a sample is an important one. As Haines *(2)* says, the use of a few cc. of white or yolk may cause small numbers of organisms to be overlooked. Where a determination of numbers of bacteria is being made, missing a few bacteria may not be important. Where a determination of the number of eggs containing bacteria is desired, failure to detect even a single organism may greatly affect the results. On the other hand, using all the egg contents as an inoculum in broth may enable "strays" or air contaminants to flourish in the rich egg-broth mixture, and give misleading results.

Experimental Procedure

It had been found in this laboratory that the methods commonly used did not sterilize the shell. Five eggs immersed in $HgCl_2$ (1-1000) and 10 in phenol (5 percent) for 1 hour showed growth when transferred to 100 cc. of thioglycollate medium. This experiment was repeated with 18 eggs immersed in $HgCl_2$ for 30 minutes. These were removed and drained. Six were placed in thioglycollate broth and the remaining 12, held in tongs, were dipped in 95 percent alcohol, which was burned off. Six of these were cultured and the other 6 were carefully flamed with a Bunsen burner, after which they were placed in thioglycollate medium. All 18 eggs showed growth in 48 hours or less. It was felt, however, that one end of the egg could be flamed more thoroughly than the whole egg and that the possibility of contaminating the egg contents after such treatment was very slight. Therefore, the following procedure was adopted for examining shell eggs.

Eggs were immersed in 1-1000 $HgCl_2$ for 30 minutes and drained. Then each egg, held in wire tongs, was dipped into 95 percent alcohol and the alcohol burned off. The small end was carefully and thoroughly flamed in a Fisher burner. With the aid of a flamed knife and tweezers, a piece of the shell approximately ¼ inch in diameter was removed from the small end. The contents of the egg were dropped into a wide-mouthed, rubber-stoppered jar containing 25 cc. of double strength Fluid Thioglycollate Medium (Difco). To aid in expelling the contents, it was sometimes necessary to make a small opening in the large end by a sharp blow with the knife. The yolk membrane was punctured either in the egg or in the jar with the sharp tip of the knife. The egg-broth mixture was thoroughly shaken and incubated at room temperature for 3 days. At the end of that time the jar was agitated and a 4 mm. loopful of the mixture was transferred to a tube containing 25 cc. of single strength thioglycollate medium. Presence or absence of growth was recorded after 3-4 days incubation at room temperature. Often transfers from jar to tube were unnecessary; positive cultures could be recognized by a typical coagulation of the egg-broth mixture. Air contamination in the small room was held down by spraying and/or use of a triethylene glycol vaporizer. The eggs used were gathered daily from a flock of White Leghorn-Rhode Island Red crossbred hens. Eggs to be held were placed under the desired conditions the same day they were laid; those used as controls were checked bacteriologically within an hour of the time they were gathered. Eggs selected were clean, with normal shape and good shell.

Preliminary work by one of us (NHS) resulted in the development of the following procedure for holding eggs to be examined:

Thirty eggs were placed, large end up, on wire screens in each of a number of desiccators. Each desiccator contained a saturated salt solution which would keep the humidity between 90 and 95 percent. The solutions used were $ZnSO_4$ for 41° F. (5° C.), Na_2CO_3 for 59° F. (15° C.), and $MgSO_4$-$7H_2O$ for 77° F. (25° C.) and 95° F. (35° C.). After being filled and sealed, the desiccators were dated and placed in constant temperature rooms or incubators. All the desiccators were not loaded at one time. Usually two or three desiccators were filled on a single occasion, and the schedule for examining the eggs was arranged to make the best use of the eggs, desiccators and incubator space available.

Before the experiment was begun, eggs from the same flock were examined over a period of 3 months (Sept.-Dec.) to determine the normal percentage of infection. In addition a control batch was checked each week during the course of the experiment. During the first 3-month period, 416 eggs were examined; 52, or 12.5 percent, were positive. For the later controls, 235 eggs were examined; 27, or 11.5 percent, were positive. Table 1 shows how these results compare with those of

TABLE 1

Bacterial infection of fresh eggs

Author	Year	No. of eggs	Percent infected
Rettger	1913	3510	9.5 [c]
Stiles and Bates	1912	613	87.0 [c]
Bushnell and Maurer	1914	2759	19.3 [c]
Maurer	1911	ca100	82.0
Hadley and Caldwell	1916	2520	8.7 [c]
Andresen	1932	358	5.0
Haines	1938	112	7.0 [c]
Wolk	1948-9	416	12.5
		235	11.5

[c] Yolk only.

previous workers, based on data given by Haines *(2)*. Most of the figures used from his table are for yolks, where the majority of infections seem to occur.

There is a wide divergence of results, probably due to differences in technic, but most work seems to indicate that the percentage of bacterial infection in fresh eggs is relatively low.

Results

The results of this study indicate that temperature has a direct bearing on the percentage of bacterial infection in the egg. Under favorable conditions the bacteria on the shell and in the pores multiply, increasing the possibility of penetration into the interior. Haines *(2)* pointed out that most of the saprophytes isolated from eggs grow better at 20-25° C. (68-77° F.) than at 37° C. Figure 1 shows that the percentage of infected eggs was highest at 77° F., reaching a peak of 76.6 percent in 18 days. At 95° F. the percentage of infection rose more quickly, but reached only 48.2 percent in 7 days before dropping off. At 59° F. the high point of 37.9 percent was reached in 16 days, and the peak of 26.6 percent infection at 41° F. occurred at 18 days. In all cases there was a sharp drop after the peak; at 95° F. the percentage was roughly the same from 12 to 21 days. This decline was probably due to the existence of conditions unfavorable to the growth and penetration of bacteria. The abrupt decrease in infected eggs on the 14th day and subsequent rise at the three lower temperatures is difficult to explain, but seems to have been more than a chance variation.

It was thought possible that this variation in percentage of infection around the 14th day might be due to a change in the type of organisms which survived. The flock of hens previously used was not available, but a young flock of similar breed, housed similarly, was used to supply the eggs for another experiment. Batches of 30 eggs each were incubated at 41° F. for 18 days, 59° F. for 12 and 16 days, 77° F. for 12 and 18 days, and 95° F. for 7 days. Eggs showing bacterial infection were subcultured into thioglycollate medium, and tryptone glucose extract agar plates were poured from these tubes. Colonies were picked after 48 hours' incubation at room temperature and streaked on agar slants. Microscopic and cultural examination showed that, of 45 cultures isolated from incubated and fresh eggs, 28 were micrococci, 10 were Gram negative rods (mostly Pseudomonas sp.), 5 were sporeformers of the *B. subtilis* group, and 2 were yeasts. These figures do not represent the relative numbers of each type of bacteria present.

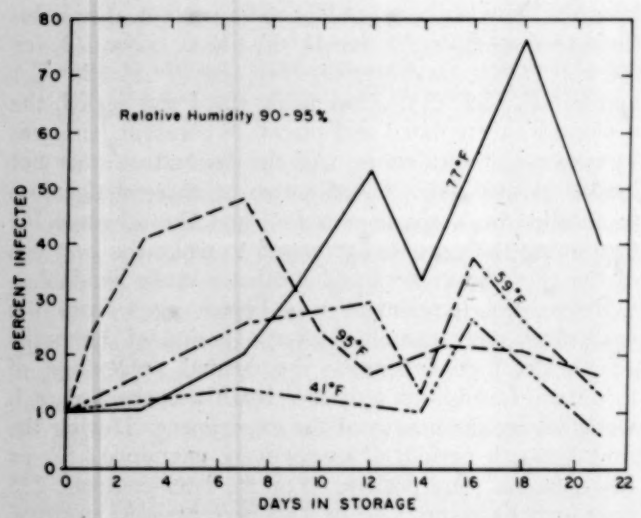


FIG. 1. Bacterial infection of shell eggs held at several temperatures.

There were no significant differences in the types of bacteria isolated from eggs stored at the various temperatures for varying lengths of time.

It might be well to mention that molds grew luxuriantly under these storage conditions, especially at 59°, 77°, and 95° F. After about two weeks, the molds penetrated sufficiently to cause many stuck yolks. However, mold growth could be distinguished easily from bacterial growth in the thioglycollate medium.

Summary and Conclusions

A technic for the bacteriological examination of shell eggs has been presented. This method requires the culture of the whole egg in double-strength fluid thioglycollate medium, followed by subculture of the egg-medium mixture.

The bacteriological examination of fresh eggs (probably less than 8 hours old) indicates that the percentage of infection is about 12 percent.

Change in the percentage of infection in eggs stored at high humidity is, in general, directly proportionate to the storage temperature.

At the end of 21 days, the bacterial infection was down to approximately that of fresh eggs, except at 77° F., but growth of molds on and in the eggs under stated conditions of temperature and humidity rendered them inedible.

LITERATURE CITED

1. HADLEY, P. B., AND CALDWELL, D. W. The bacterial infection of fresh eggs. R. I. Agric. Exp. Sta. *Bull.*, **164** (1916).
2. HAINES, R. B. Microbiology in the preservation of the egg. Food Invest. Spec. Rep. No. 47, H. M. Stationery Office, London (1939).
3. MAURER, O. Bacteriological studies on eggs. Kans. Agric. Exp. Sta. *Bull.*, **180** (1911).
4. PENNINGTON, M. E. A chemical and bacteriological study of fresh eggs. *J. Biol. Chem.*, **7**, 109 (1910).
5. RETTGER, L. F. The bacteriology of the hen's egg. Storrs (Conn.) Agric. Exp. Sta. *Bull.*, **75** (1913).
6. RETTGER, L. F., AND STONEBURN, F. H. Bacillary white diarrhea of young chicks. Storrs (Conn.) Agric. Exp. Sta. *Bull.*, 68 (1911).
7. Standard Methods for the Examination of Dairy Products. 9th Edition (1948) American Public Health Assn.
8. STILES, G. W., AND BATES, C. A bacteriological study of shell, frozen, and desiccated eggs. U.S.D.A. *Bull.*, **158** (1912).

Adaptation of the Tenderometer for the Quantitative Determination of Firmness in Calcium-Treated Apple Slices

D. G. GUADAGNI

Western Regional Research Laboratory, Albany, California*

(Received for publication, May 29, 1950)

Data are presented to show reliability of the tenderometer for measurement of firmness of cooked apple slices. The firmness values obtained using a simple test-cooking procedure reflected accurately the firmness obtained in actual pie baking. The method appears suitable for control work in calcium treatment for firming apple slices.

The interest of the Western Regional Research Laboratory in the development of dehydrofreezing and in improvement of methods of freezing preservation has led to studies of the effects of calcium firming as a pretreatment for apple slices. Since the tenderometer has been considered for firmness measurements on various products *(3, 4, 5, 6)*, it was adapted for quantitative determination of firmness of calcium-treated apple slices. With some modification this instrument is sensitive to degrees of firmness resulting from treatment with varying amounts of calcium. Measurements have been made on steam-blanched slices, which accurately represent the firmness of similar samples baked in a pie. Results obtained thus far are being released at present owing to active interest in problems of texture measurement and in methods of firming cold-stored apples.

Preparation of the Fruit

California Newtown Pippin apples which had been stored at 35° F. for approximately ten months were peeled, cored, and sliced into twelfths. Approximately twelve pounds of the slices were submerged for ten minutes in each of a number of solutions containing 0.2 percent sulfur dioxide (added as sodium bisulfite) and various amounts of calcium chloride, calcium sulfate, or calcium citrate.

In preparation for the tenderometer measurements, approximately 1200 grams of drained slices (sufficient for six to seven tenderometer readings) from each treatment were weighed to the nearest gram and spread on stainless-steel wire trays so as to eliminate overlapping. The slices were then blanched for ten minutes at 210 to 212° F., cooled for two minutes in water at 15° C., and drained for five minutes.

Standardization of the Tenderometer

It is assumed that the reader is familiar with the normal standardizing procedure which is given in the manufacturer's instruction pamphlet *(1)*. Since the smallest weight (WCT 136A) supplied with the instrument was too heavy to give satisfactory readings on blanched slices, the tenderometer was standardized with a lighter weight (about half that of WCT 136A). By adjusting the position of this weight on the pendulum arm, the instrument was balanced against exactly one-half the weight required for WCT 136A. The data in Table 1 show that the readings obtained with this special arrangement, when multiplied by one-half, are not significantly different from the readings given by the standard weight WCT 136A. The firmness values presented in the other tables may be converted to pounds per square inch by multiplying the given values by one-half.

TABLE 1

Firmness Values Obtained on Calcium-Treated Apple Slices with Tenderometer Equipped With Standard Weight and With Specially Devised Half Weight

Sample No.	Readings (lbs. shearing force/sq. in. grid area)	
	With Special Weight	Standard Weight
	(Values/2)	*(WCT 136A)*
1	19.8	20.0
2	20.5	20.0
3	20.5	21.0
4	21.0	22.0
5	21.0	22.5
Mean	20.6	21.1

Effect of Sample Weight on Tenderometer Value

It appears (Table 2) that fairly wide variations in the weight of the sample cause no significant difference in the tenderometer values, provided the test chamber is not less than approximately three-quarters full. Smaller samples give readings which are significantly lower and not nearly as uniform. Accordingly, all tenderometer readings shown in the other tables were obtained with a level-full test chamber rather than with a definite weight.

TABLE 2

The Effect of Sample Weight on Tenderometer Reading

	160 grams (level full)	120 grams (¾ full)	80 grams (½ full)
	19.5	20.0	16.0
	21.5	20.0	13.5
	22.0	20.0	11.0
	20.5	21.0	15.0
	18.5	19.0	18.0
Means	20.4	20.0	14.7

Reproducibility of Firmness Values

In order to determine the number of samples required for representative readings from each treatment, 20 readings were taken from each of two calcium treatments representing different firmness values. The individual readings and statistical data are presented in Table 3. There is no significant difference between the means of 5 and of 20 readings. The variation among readings is fairly small and evenly distributed throughout the whole range of values. Therefore, five readings are sufficient to give a fairly accurate representation of the relative firmness due to the various treatments employed.

* Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, United States Department of Agriculture.

TABLE 3

Variation in Firmness Values of Blanched Newtown Pippin Apple Slices

Treated with 0.1 Percent Calcium Chloride

Sample No.	Tenderometer Reading	Sample No.	Tenderometer Reading	Sample No.	Tenderometer Reading	Sample No.	Tenderometer Reading
1	16.0	6	18.0	11	18.0	16	17.0
2	17.0	7	16.5	12	15.0	17	17.5
3	15.0	8	16.5	13	15.0	18	15.5
4	16.0	9	15.0	14	16.0	19	16.0
5	17.0	10	17.5	15	15.0	20	17.0
Means	16.20[b]		16.45[c]		....		16.33[d]
Standard deviation	0.84		0.99		....		1.03
Standard error	0.38		0.31		....		0.23

Treated with 0.5 Percent Calcium Chloride

Sample No.	Tenderometer Reading	Sample No.	Tenderometer Reading	Sample No.	Tenderometer Reading	Sample No.	Tenderometer Reading
1	22.0	6	21.0	11	21.5	16	21.0
2	21.5	7	22.0	12	21.0	17	21.5
3	21.0	8	22.0	13	22.0	18	23.0
4	22.0	9	23.0	14	23.0	19	23.5
5	23.5	10	22.0	15	21.0	20	22.0
Means	22.0[b]		22.0[c]		....		21.98[d]
Standard deviation	0.296		0.248		....		0.264
Standard error	0.132		0.079		....		0.059

[b] First five readings.
[c] First ten readings.
[d] All twenty readings.

Effect of Weight Changes During Blanching and Cooling

In early experiments, controls gained from 13 to 15 percent in weight during blanching and cooling, while samples treated with 1.0 percent calcium chloride lost 14 to 15 percent during the same heating and cooling treatment. Hence, the effect of weight change on tenderometer reading was investigated. Large samples of both calcium-treated and plain sulfured slices were blanched as usual but, immediately after heating, half of each batch was cooled in air and half in water. The air-cooled samples were placed in the draft of an electric fan for 7 minutes, thus allowing additional moisture loss through evaporation. In this experiment the calcium-treated slices were water-cooled for 10 minutes to allow greater water absorption and thus accentuate the moisture difference between water-cooled and air-cooled slices. From the data in Table 4 it is apparent that regardless of the firming treatment employed, gain or loss of moisture, per se, during cooling in air or in water, does not significantly affect the tenderometer value. Therefore, the observed differences in tenderometer readings can be attributed to variations in firmness caused by application of varying amounts of calcium, even though the weight of the treated slices progressively decreases as the calcium concentration in the dipping solution is increased (Table 5). It appears that increasing amounts of calcium cause increasing surface hardening, which apparently prevents absorption of water during the normal cooling time employed in these experiments.

TABLE 4

The Effect of Weight Change During Blanching and Cooling on the Tenderometer Reading of Sulfur-Dioxide and Calcium-Treated Apple Slices

Tenderometer Values

Dipped in 1% Calcium Chloride		Dipped in Saturated Calcium Citrate		Sulfur Dioxide Treated (0.2%)	
Air cooled 32% wt. loss	Water cooled 5% wt. gain	Air cooled 30% wt. loss	Water cooled 6% wt. gain	Air cooled 26% wt. loss	Water cooled 10% wt. gain
33.0	33.0	13.0	14.0	6.5	6.5
32.0	31.0	12.5	13.0	9.0	8.0
32.5	30.0	14.5	12.5	8.5	7.0
32.0	30.0	12.0	12.0	7.0	7.5
....	....	12.0	12.0	5.5	5.5
Means 32.4	31.0	12.8	12.8	7.3	6.9

TABLE 5

The Effect of Calcium on Weight Change and Tenderometer Value During Blanching and Water Cooling

Calcium Ttreatment	Percent Weight Change	Tenderometer Value [e]
None	+ 14	7.0
Saturated calcium citrate	+ 8	14.1
0.1 Percent calcium chloride	+ 4	16.4
Saturated calcium sulfate	0	21.2
0.5 Percent calcium chloride	— 4	26.0
1.0 Percent calcium chloride	— 14	33.5

[e] Represents averages of five separate readings.

Relation between Pie-Baked and Steam-Blanched Slices

Several samples of both calcium-treated and non-calcium-treated slices were steam-blanched 10 minutes, water-cooled, and tested in the tenderometer. Similar samples were baked in pies at 475° F. for 30 minutes. After cooling overnight at room temperature, the baked slices were tested in the tenderometer in the same manner as the blanched slices. Since the two different methods of cooking resulted in approximately the same tenderometer readings, no additional blanching times were attempted. Considerably more variation was found in the pie-baked slices, probably due to the fact that the pies were not evenly heated throughout. As shown in Table 6, however, when the mean of the readings obtained from a whole pie is compared with the mean of a similar number of readings on steamed slices, the results of the two methods agree very well. Therefore, the tenderometer in conjunction with the steam treatment is particularly useful in predicting the firmness of apple slices baked in pies. In addition to saving time and materials, it also gives a more reliable and reproducible value than can be expected from the usual subjective methods of texture evaluation.

TABLE 6

Relationship Between the Firmness of Steam Blanched and Pie Baked Apple Slices

Calcium Treatment	Tenderometer Readings [f]	
	Steam Blanched	Pie Baked
None	6.3	6.6
Saturated calcium citrate	10.2	10.8
.1 Percent calcium chloride	14.5	12.1
Saturated calcium sulfate	21.2	22.3
.5 Percent calcium chloride	22.5	22.1
.7 Percent calcium chloride	26.6	26.6

[f] Represent averages of four or more readings.

Applicability to Other Varieties

Limited trials indicate that the method can be applied to other varieties such as Rome Beauty, Jonathan, Winesap, and Gravenstein. Preliminary tests on these varieties revealed that pre-freezing treatments such as

steam blanching, sulfiting, and sirup filling *(2)* caused significant differences in firmness after freezing, thawing, and testing by the method outlined herein. In varieties which occasionally contain stringy tissue, such as the Delicious, the tenderometer is not sensitive to small differences in firmness.

Summary and Conclusions

With suitable modification the tenderometer is a satisfactory instrument for the objective determination of firmness in blanched Newtown Pippin apple slices treated with calcium.

Under the conditions of these experiments the firmness of steam-blanched, water-cooled slices is essentially the same as the firmness of pie-baked slices.

REFERENCES

1. Food Machinery Corporation *Bull.* No. 5, Tenderometer 1941.
2. Guadagni, D. G. Sirup treatment of apple slices for freezing preservation. *Food Technol.*, 3, 404 (1949).
3. Jenkins, R. R., and Lee, F. A. Tenderometer readings as an index of quality of fresh asparagus. *Food Res.*, 5, 161 (1940).
4. Lee, F. A. Judging the maturity of raw lima beans. *Food Ind.*, 15, 70 (1943).
5. Lee, F. A., and Oberle, G. D. The use of the tenderometer for the determination of the firmness of apples, peaches and pears. *Fruit Prod. Jour.*, 27, 244 (1948).
6. Martin, W. McK. The Tenderometer. An apparatus for evaluating tenderness in peas. *Canning Trade*, 59, 7 (1937).

Nature of Thermal Death Time Curves for P. A. 3679 and Clostridium Botulinum[a]

C. R. STUMBO,[b] J. R. MURPHY[b] AND JEANNE COCHRAN

Food Machinery and Chemical Corporation, San Jose, California

(Received for publication, May 29, 1950)

Current interest in high-temperature short-time processing of foods demands consideration of bacterial spore resistance to temperatures in the higher range. Results of work covered in numerous publications relative to thermal resistance of bacterial spores have been indecisive as to whether or not thermal death time curves are straight when the curves represent spore resistance to temperatures above about 245° F. (118.3° C.). This paper presents results of a two-year study relative to the nature of such curves for spores of P. A. 3679 and Clostridium botulinum suspended in a variety of food products and subjected to temperatures between 220° F. (104.4° C.) and 270° F. (132.2° C.). Methods employed in the study and the applicability of results obtained, to the evaluation of thermal processes for foods, are discussed.

Current interest in high-temperature short-time processing of foods has emphasized a need for information relative to the resistance of important food spoilage bacteria to temperatures higher than those commonly employed in processing. A number of reports *(1, 2, 6)* have appeared in which it has been indicated that thermal death time curves may not be straight lines when the curves are plotted on semi-logarithmic coordinates, temperature being plotted on the linear scale and thermal death time on the log scale. This has been indicated especially for curves representing resistance of bacteria to temperatures above about 245° F. (118.3° C.) Because of the nature of methods employed, the acuracy of thermal resistance data heretofore obtained for bacterial spores subjected to the higher temperatures seemed to be subject to considerable question. It was believed possible that the noted curvatures of thermal death time curves might well be the result of plotting inaccurate thermal resistance values.

The importance of establishing the nature of curves representing bacterial spore resistance to the higher temperatures lies in the fact that all mathematical and graphical methods of process determination involve the use of data obtainable only from such curves. Mathematical methods are based on the assumption that the curves are straight lines for the temperature range employed in processing. Therefore, the study reported herein was undertaken to establish more exactly the nature of thermal death time curves for P. A. 3679 and *Clostridium botulinum* spores suspended in various media and subjected to temperatures in the range 220° F. (104.4° C.) to 270° F. (132.2° C.).

The technique described elsewhere *(4)* for studying thermal resistance fo bacteria to temperatures in the higher range was employed throughout this investigation. Because the bacteriological methods employed in connection with this technique were different in many respects from those which have been used in connection with other methods of measuring thermal resistance, they will be described in some detail in the hope that they may prove valuable to others interested in thermal resistance studies.

Experimental Methods and Results

Media for spore production. A liver broth, which is prepared as follows, was employed for production of spores of P. A. 3679. Bacto liver is added to distilled water in the amount of 75 g. of liver per liter of water. The mixture is brought to boiling temperature and allowed to boil slowly over an open flame for five minutes. Ten g. proteose-peptone, one g. di-potassium

[a] Presented before the Tenth Annual I. F. T. Convention, Chicago, Illinois, May 22, 1950.

[b] Present address: Department of Horticulture, The State College of Washington, Pullman, Washington.

phosphate, and three g. yeast extract are then added per liter of broth. After solution of these latter ingredients the reaction of the medium is adjusted to pH 7.4, approximately, and the original volume reconstituted, if necessary, with distilled water. While the liver particles are kept uniformly suspended, the medium is distributed in six-ounce screw-cap bottles containing approximately one half inch of glass beads, about 90 ml. of medium being placed in each bottle. The bottles of medium are autoclaved for thirty minutes at fifteen pounds steam pressure to accomplish sterilization.

A beef heart medium,[c] which is prepared as follows, was employed for production of *Cl. botulinum* spores. Ground lean beef heart (fresh) is added to distilled water in the amount of 454 g. heart per liter of water. The mixture is brought to boiling temperature and allowed to boil slowly over an open flame for one hour. The infusion is then filtered through cheese cloth, to separate the coarser heart particles from the broth. The filtrate (broth) is then reconstituted with distilled water to a volume equal to that of water originally used. To each liter of reconstituted broth is added:

5 g. Isoelectric casein
10 g. Tryptone
10 g. Gelatin
0.5 g. Glucose
4 g. di basic potassium phosphate
3 g. Sodium citrate

The broth is heated over an open flame, while it is being constantly stirred, until all ingredients are in solution. After adjusting the reaction of the broth to pH 8 to 9, it is distributed in six-ounce screw-cap bottles. Heart particles, separated in the above filtering operation, are then added to a depth of about one inch in each bottle. The bottles of medium thus prepared are capped and autoclaved at 15 pounds steam pressure for 30 minutes. After sterilization the pH of the medium is usually near seven.

Production of spore suspensions. Each bottle of media prepared as described above was inoculated with one ml. of an actively growing culture of the test organism (P. A. 3679 or *Cl. botulinum*). The inoculated bottles of media were then autoclaved for ten minutes at five p.s.i.g. steam pressure, to exhaust entrapped air, and subsequently incubated at 85° F. (29.4° C.) for a period of 13 days. The resulting culture of each test organism was examined for purity, mixed thoroughly in a sterile Waring blendor and filtered aseptically through a glass wool pad between layers of cheese cloth to remove undigested meat particles and minimize spore clumps. These filtrates (spore suspensions) were then placed in sterile six-ounce bottles and kept stored at approximately 40° F. (4.4° C.).

Estimation of Spore Concentrations. A method, in which the thermoresistometer *(4)* was used for destroying vegetative cells and activating spores in the suspensions, was employed for estimating spore concentrations. By this method, serial decimal dilutions of a spore suspension were made in distilled water (unless otherwise noted) so as to obtain from 20 to 80 spores per ml. in the final dilution, the range of dilutions being judged from results of range finding determinations made in the same manner as were the sport count determinations, but with fewer replicate samples. One hundredth ml. of the final dilution was placed in each of 90 thermoresistometer cups. These 90 samples were then subjected to a pasteurization treatment in the thermoresistometer, each sample at the end of the pasteurization treatment being automatically introduced into a tube of pork infusion agar[d] which had been liquefied by heating just prior to the introduction of the sample. The temperature of the agar was in the range of 120° F. (48.9° C.) to 150° F. (65.6° C.) when the samples were introduced.

Pasteurization treatment consisted of exposing the spores to 220° F. (104.4° C.) for 0.464 minutes in the case of P. A. 3679 and to the same temperature for 0.233 minutes in the case of *Cl. botulinum*. These time-temperature relationships were determined experimentally and represent those which gave maximum spore counts. Less severe heat treatments though adequate for destroying vegetative cells apparently were inadequate to activate some of the spores to germinate. However, the relationships used may still have been inadequate to accomplish maximum activation even though more severe treatments resulted in lower counts. This could occur if more severe heating is required to activate some spores than to kill others. Recent studies indicate that this is probably the case and that maximum spore counts may be only rarely, if ever, obtained by spore counting techniques employing pasteurization.

Subsequent to the pasteurization procedure, the 90 tubes containing the heated samples were allowed to stand quietly until the agar had solidified. On the agar in each tube was then layered a small quantity (about 2 ml.) of warm sterile sealing mixture (one part paraffin, one part vaseline, and four parts paraffin oil). A sealing mixture of this composition, upon cooling, congeals sufficiently to form an excellent seal but doesn't separate from the walls of the tubes or become brittle.

Cultures thus prepared were incubated at 85° F. (29.4° C.) until a period of ten days elapsed during which no growth appeared in tubes negative for growth prior to the beginning of the ten day period. Upon completion of this arbitrarily chosen incubation period the number of tubes showing growth was determined. Growth in this medium may or may not be accompanied by gas formation and splitting of the agar. However, since it is a clear medium when properly prepared, growth in it is easily recognized.

The most probable number of spores ($\bar{x}$) per ml. of the dilution from which the samples were taken was estimated from the equation given by Halvorson and Ziegler *(3)*. The equation as applied follows:

[c] Formulated in the American Can Company Research Laboratories, Maywood, Illinois.

[d] For all subculturing, Yesair's medium as described by Wynne and Foster *(7)* was used. In removing the precipitate resulting from boiling, it has been found expedient to allow the medium to solidify in the container, then remove the agar block and trim off that containing the settled precipitate. Other commonly used subculture media were tried, but found inferior to the fresh pork infusion agar.

$$\bar{x} = \frac{2.3026}{a} \log \frac{n}{q}$$

where:

a = volume of sample (ml.).
n = total number of tubes (or samples).
q = number of tubes in which growth did not occur.

Then,

$\bar{x}$ times the dilution factor was considered to equal the number of spores per ml. of the original suspension.

Spore counts. All resistance data reported here for P. A. 3679 suspended in the various media, except evaporated milk and cream, were for a single suspension of spores. Five replicate counts of spores in this suspension were made on different days. The number of spores per ml. of original suspension observed for each of the determinations was as follows:

Determination	Count
1	20,900,000
2	25,200,000
3	37,300,000
4	20,900,000
5	23,800,000

The average of these values (25,600,000) was taken as the number of spores per ml. of the original suspension. Another culture was used in preparing the suspension employed for determining resistance of the organism in evaporated milk and cream. The number of spores per ml. of this suspension, estimated in the same manner as described above, was found to be 51,100,000.

For the suspension of *Cl. botulinum*[6] spores, it was found that a slightly higher count was obtained if the spores were suspended in M/15 neutral phosphate when pasteurized, therefore, this variation was incorporated in the counting procedure. Otherwise the procedure used was exactly as described above. The number of spores in the suspension employed for resistance determinations was estimated to be 422,000,000 per ml.

Counts of the spores in the three suspensions were made periodically during their storage at 38° F. (3.3° C.) to 40° F. (4.4° C.). It was found that no detectable variations in counts occurred as a result of storage for as long as 30 months in the case of P. A. 3679 and 18 months in the case of *Cl. botulinum*. No studies were made on the respective spores stored for longer periods.

Preparation and heating of food samples. In preparing the inoculated food samples, 0.01 ml. of an appropriate dilution of the whole culture (spore suspension) in sterile distilled water, and approximately 0.01 ml. of suspending medium were placed in each cup, mixed with a sharpened inoculating needle, and spread uniformly over the inside surface of the cup.

After sterilization of the three steam chambers of the thermoresistometer, the steam pressure in the center chamber was adjusted to correspond to the desired temperature, and the pressure released from the other two chambers (see reference 4 for a description of this instrument). An aluminum boat (fluted edge) was placed in each of the six holes in the carrier plate, a small cup containing the sample was placed in each boat, and the samples were drawn into the center chamber. At the end of the prescribed heating period, the pressure was released from the chamber and the cups were drawn from the chamber to the position from which they dropped into tubes of sterile culture medium (pork infusion agar). After the inoculated agar had cooled, it was layered with sealing mixture and the tubes were placed in the incubator controlled at 85° F. (29.4° C.). The subculture tubes so prepared were observed periodically during a prescribed incubation period and the number of tubes positive for growth recorded. At the end of this period the number of spores surviving certain of the heat treatments were determined and the time required for destruction of 90 percent of the spores calculated.

Method of treating data. Assuming the logarithmic order of death to obtain,[7]

$$D = \frac{U}{\log a - \log b} = \text{time}^{8} \text{ (in minutes) to accomplish a 90 percent reduction in number of spores.}$$

In this equation "U" is equal to the time of heating. The symbol "a" represents the number of spores subjected to one time-temperature relationship, that is, the number of spores initially present per sample multiplied by the number of replicate samples, the number per sample being governed by the quantity of original spore suspension used. The symbol "b" represents the number of spores surviving at the end of heating time "U." In this study, each value of *b* was arrived at by applying the equation of Halvorson and Ziegler *(3)* to data obtained for samples subjected to a time-temperature relationship which sterilized only a portion of the total number of samples. The equation as applied in this case follows:

$$\bar{x} = 2.3026 \log \frac{n}{q}$$

where:

$\bar{x}$ = most probable number of spores surviving per replicate sample.
n = total number of replicate samples.
q = number of sterile samples as evidenced by lack of growth in subculture tubes.

Then,

the value of *b*, the most probable number of spores surviving the time-temperature relationship to which the samples were subjected, was obtained by multiplying $\bar{x}$ by the number of replicate samples.

[6] Strain 62A obtained from Mr. C. T. Townsend, National Canners Association, San Francisco, California.

[7] Limited information in this regard, collected during the course of these studies, indicated that the order of death of the spores employed was either strictly logarithmic or so nearly so that assuming such to be the case could cause only very minor errors in the values used for plotting thermal death time curves. Time did not permit of the exhaustive study this point deserves.

[8] Time required for 90 percent destruction has previously been designated by the symbol Z (Zeta) but because of confusion of this symbol with z, representing slope of the thermal death time curve, it has been agreed by workers in the field to use the symbol D hereafter instead of Z.

It may be noted that the method described above for arriving at values of *a* and *b* is different from that described in earlier publications *(4, 5)*. In the method described earlier it was assumed that when growth did not appear in all replicate subculture tubes, growth in any single tube resulted from the germination of a single spore. Statistically this should be true only when the proportion of positive tubes is very small. Therefore, the above described method of treating data is believed to give more reliable values for the terms *a* and *b*, though it should be pointed out that D values calculated from corresponding values arrived at by the two methods are usually almost identical.

Quite frequently when using a series of time-temperature relationships representing heat treatments of increasing severity, a fraction but not all of the replicate samples subjected to any one of a number of time-temperature relationships will be sterilized. When such occurred in the study reported here, a D value has been calculated from data obtained corresponding to each time-temperature relationship which sterilized only a fraction of the samples. D values calculated from data obtained for spores of a particular organism suspended in one medium and subjected to one temperature were averaged to give a D value to use in constructing a thermal death time curve. This would seem to be a justifiable procedure when the statistical treatment described above is used to determine the most probable number of spores surviving a heat treatment.

When values of D thus determined are plotted against corresponding temperatures on semi-logarithmic coordinates, D being plotted on the log scale and temperature on the linear scale, thermal death time curves are obtained which represent the time required at the respective temperatures to reduce the initial number of spores by 90 percent. Values of the term z appearing in mathematical formulae for process calculation may be determined from these thermal death time curves, any given value of z being equal to the number of degrees F. required for a curve to traverse one log cycle.

Thermal resistance studies. Data have been obtained for spores of P. A. 3679 and *Cl. botulinum* heated while suspended in a number of foods and other media. The food products used here, except the unsterilized milk and the cream, were commercially packed; therefore, the thermal resistance values shown may be different from those which would be obtained for spores of the same organisms suspended in the unprocessed foods. However, the nature of the thermal death time curves (straight or otherwise) should be approximately the same for spores suspended in processed and unprocessed foods.

For the studies in which P. A. 3679 was used as the test organism, each sample of food, except milk and cream, was inoculated with 25,600 spores. Each sample of milk was inoculated with 51,100 spores. The distilled water samples contained 256 spores each. For the studies in which *Cl. botulinum* was used as the test organism, each sample was inoculated with 42,200 spores. Immediately subsequent to inoculation, six replicate samples of the suspending medium under study were subjected to each time-temperature relationship employed. The subcultures were incubated at 85° F. (29.4° C.) for a period of three to six weeks, the incubation period exceeding, by at least ten days, the longest time required for any detectable germination to occur. It should be noted in this connection, especially in view of the results reported by Wynne and Foster *(7)*, that in no experiment did all the spores which survived the more severe heat treatments germinate in anything like a period of three days' incubation. Commonly no more than half the survivors had germinated in three days and seldom was germination complete even after a period of two weeks' incubation. Further studies relating to the causes of delayed germination are now in progress.

Data obtained for spores of P. A. 3679 suspended in pureed peas are given in Table 1. In order to conserve space, and because all experiments were organized and conducted similarly, complete data are being presented only for this one experiment. This is believed adequate to demonstrate the scope of each of the experiments

TABLE 1

Thermal resistance data[b] for P. A. 3679 spores suspended in pureed peas (25,600 spores per replicate sample—153,600 spores in six samples subjected to each time-temperature relationship).

Temperature (° F.)											
220				230				240			
U	No. + Tubes	b	D	U	No. + Tubes	b	D	U	No. + Tubes	b	D
92.8	6	....	....	25.8	6	....	....	7.1	6	....	....
139.3	6	....	....	38.8	6	....	....	10.7	6	....	....
185.7	6	....	....	51.7	6	....	....	14.3	6	....	....
232.1	6	....	....	64.6	6	....	....	17.8	6	....	....
278.5	5	10.8	67.0	77.5	6	....	....	21.4	4	6.60	4.90
324.9	5	10.8	78.3	90.4	2	2.43	18.8	25.0	2	2.43	5.20
371.4	3	4.16	81.4	103.4	0	....	....	28.5	1	1.09	5.54
250				260				270			
2.00	6	....	....	0.52	6	....	....	0.157	6	....	....
3.00	6	....	....	0.85	6	....	....	0.236	6	....	....
4.00	6	....	....	1.13	6	....	....	0.313	6	....	....
5.00	6	....	....	1.41	5	10.8	0.340	0.393	3	4.16	0.086
6.00	4	6.60	1.38	1.70	2	2.43	0.354	0.472	0	....	....
7.00	4	6.60	1.61	1.98	0	....	....	0.548	0	....	....
8.00	1	1.09	1.56	2.26	0	....	....	0.628	0	....	....

[b] Symbols in table refer to following:
U = time of heating in minutes.
b = Most probable number of spores responsible for indicated number of positive tubes.
D = Calculated time (in minutes) required for destruction of 90 percent of spores.

TABLE 2

Calculated time for 90 percent destruction of P. A. 3679 spores suspended in various media and subjected to the indicated temperatures.

Temp. ° F.	Average D Values for P. A. 3679 Spores in Following Products									
	Pureed Peas	Strained Squash	Whole Kernel Corn	Uncooked Fresh Pork	Cooked Fresh Pork	White Sauce	Distilled Water	Unsterilized Evaporated Milk	Presterilized Evaporated Milk	Unsterilized 20% Cream
220	75.6	32.6	73.4	49.7	58.6	....	36.9	....	....	....
230	18.8	10.0	16.7	15.6	17.7	....	10.2	12.7	14.0	15.6
240	5.21	3.02	4.27	....	4.64	4.16	3.04	4.38	3.84	4.91
250	1.52	0.85	1.18	1.39	1.21	1.23	0.80	....	1.29	1.52
260	0.347	0.222	....	0.290	0.319	0.299	0.198	0.457	0.400	0.384
270	0.0860	0.0645	0.0716	0.0924	0.0808	0.0717	0.0496	....	....	....

and the nature of data obtained for spores of both organisms suspended in the different media employed. Values of D for spores of P. A. 3679 suspended in the different media and subjected to the indicated temperatures are summarized in Table 2. Values of D for spores of *Cl. botulinum* are summarized in Table 3. Each of these D values was calculated as described in the preceding section and those representing resistance of spores of either organism while suspended in a single

TABLE 3

Calculated time for 90 percent destruction of Cl. botulinum spores suspended in four different media and subjected to the indicated temperatures.

Temp. ° F.	Average D Values for *Cl. botulinum* Spores in Following Products			
	Pureed Peas	Strained Squash	M/15 Neutral Phosphate	Distilled Water
220	10.2	6.92	10.0	5.49
230	1.98	1.79	2.01	1.01
240	0.435	0.393	0.530	0.226
250	0.089	0.060	0.133	0.051
260	0.0203	0.0178	0.0325	0.0131

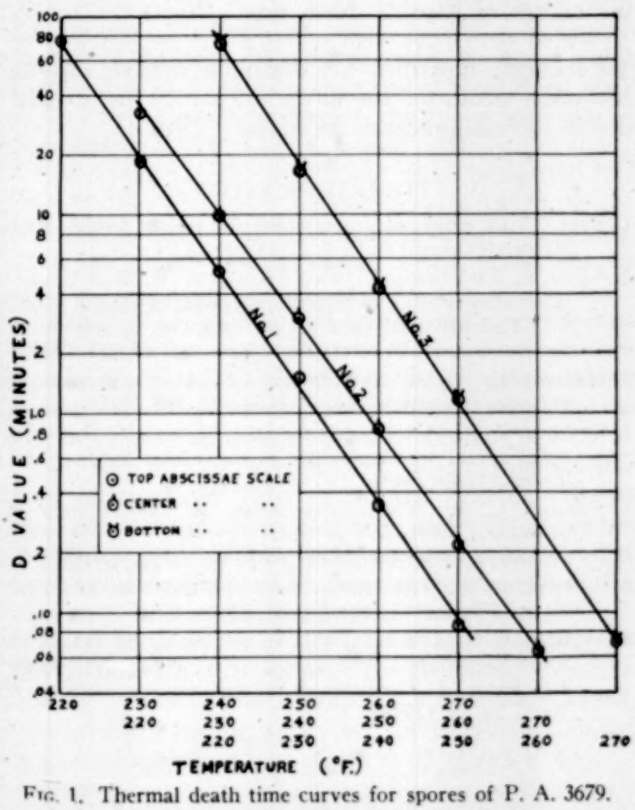


FIG. 1. Thermal death time curves for spores of P. A. 3679.

Curve No. 1. For spores suspended in pureed peas.
Curve No. 2. For spores suspended in strained squash.
Curve No. 3. For spores suspended in pureed whole kernel corn.

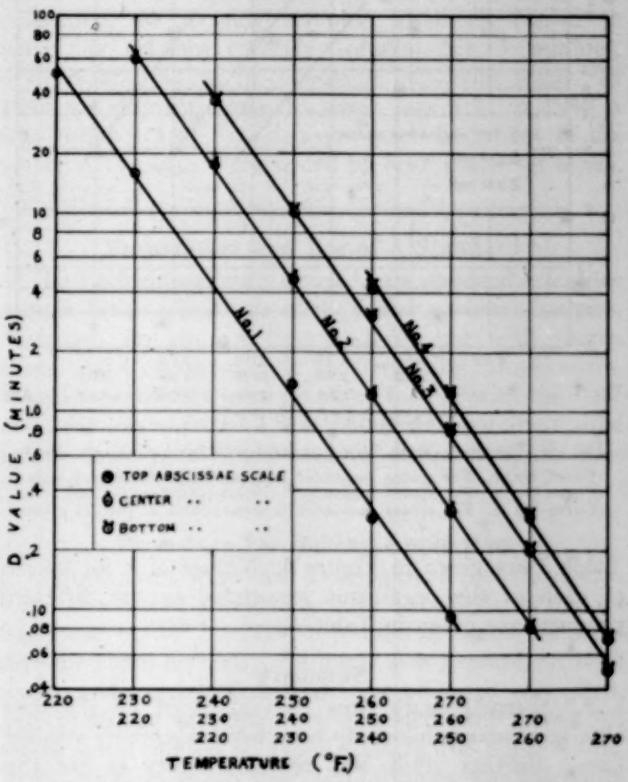


FIG. 2. Thermal death time curves for spores of P. A. 3679.

Curve No. 1. For spores suspended in finely ground uncooked pork.
Curve No. 2. For spores suspended in finely ground cooked pork.
Curve No. 3. For spores suspended in distilled water.
Curve No. 4. For spores suspended in a commercial white sauce.

product were obtained by treating data similar in scope to that appearing in Table 1 for 3679 spores in pureed peas. Thermal death time curves, for P. A. 3679 spores, based on values appearing in Table 2 are given in Figures 1, 2, and 3. Thermal death time curves, for *Cl. botulinum* spores, based on values appearing in

TABLE 4

Values of z for spores of P. A. 3679 and Cl. botulinum suspended in various media.

Product	z values	
	P. A. 3679	Cl. botulinum
Pureed peas	17.3	15.0
Strained squash	18.2	14.7
Pureed whole kernel corn	16.6	.....
Uncooked pork	18.0	.....
Cooked pork	17.5	.....
White sauce	16.6	.....
Distilled water	17.6	15.3
M/15 Phosphate	.....	16.3
Unsterilized evaporated milk	20.5	.....
Presterilized evaporated milk	19.6	.....
Unsterilized 20% cream	18.8	.....

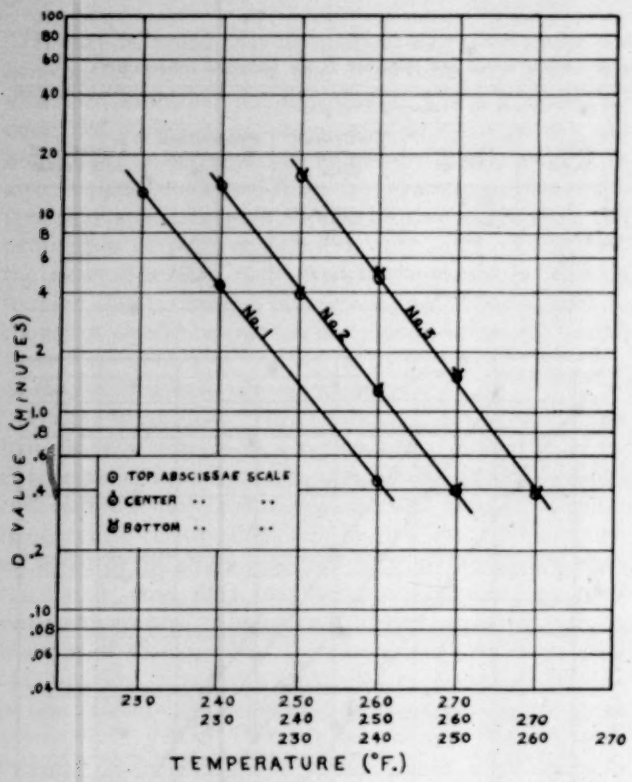


FIG. 3. Thermal death time curves for spores of P. A. 3679.

Curve No. 1. For spores suspended in unsterilized evaporated milk.
Curve No. 2. For spores suspended in presterilized evaporated milk.
Curve No. 3. For spores suspended in unsterilized 20 percent cream.

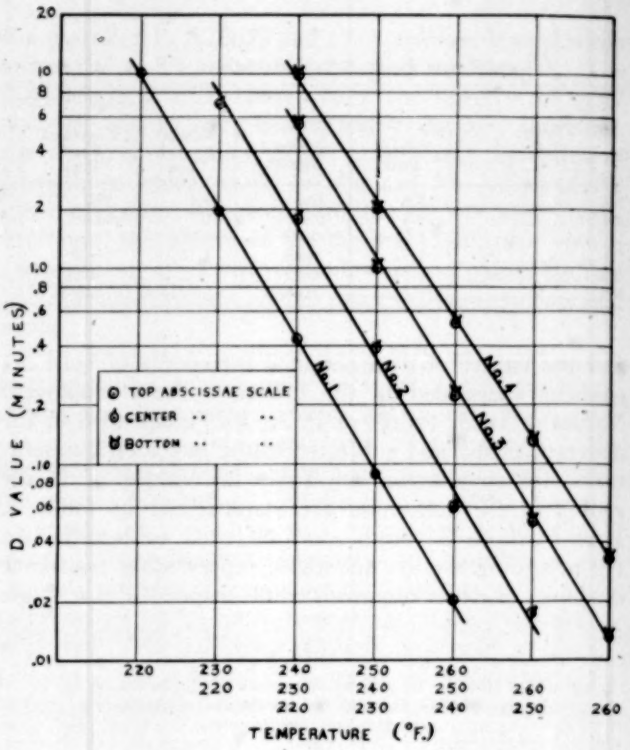


FIG. 4. Thermal death time curves for spores of *Cl. botulinum*.

Curve No. 1. For spores suspended in pureed peas.
Curve No. 2. For spores suspended in strained squash.
Curve No. 3. For spores suspended in distilled water.
Curve No. 4. For spores suspended in M/15 neutral phosphate.

Table 3 are given in Figure 4. Values of z for spores of each of the organisms suspended in the different products are given in Table 4.

Summary

All thermal death time curves, based on the data obtained during this study have been essentially straight lines. Further study will reveal whether or not this will be true for the spores of the same organisms suspended in other media, or for spores of other important food spoilage bacteria suspended in various media. Considering the scope of this study and the consistency of results obtained, straight line thermal death time curves might well be expected for spores of P. A. 3679 and *Cl. botulinum* suspended in other media. Further, there is nothing about the nature of the curves to indicate that they should not be straight lines when extended to include resistance of the spores to higher temperatures than employed in this study. However, until methods are established for making thermal resistance measurements at still higher temperatures, it cannot be concluded that the curves would be straight over the entire range of temperatures now possible to employ in commercial processing of foods.

Methods employed in this study have been described in considerable detail in the hope that such description may be of value in further work designed to obtain additional information concerning factors influencing thermal resistance and germination of spores important in the spoilage of thermally processed foods. It is believed that, in addition to contributing information on the nature of thermal death time curves, the results presented here have demonstrated the applicability of the methods described for obtaining reliable thermal resistance values for use in the calculation and evaluation of thermal-processes for foods.

LITERATURE CITED

1. BALL, C. O. Thermal process time for canned foods. Natl. Research Council *Bull.*, **7**, 37 (1923).
2. GROSS, C. E., VINTON, C., AND STUMBO, C. R. Bacteriological studies relating to thermal processing of canned meats. VI. Thermal death-time curve for spores of test putrefactive anaerobe in meat. *Food Research*, **11**, 411 (1946).
3. HALVORSON, H. O., AND ZIEGLER, N. R. Application of statistics in bacteriology. *J. Bact.*, **25**, 101 (1932).
4. STUMBO, C. R. A technique for studying resistance of bacterial spores to temperature in the higher range. *Food Tech.*, **2**, 228 (1948).
5. STUMBO, C. R. Thermobacteriology as applied to food processing. *Advances in Food Research*. Vol. II, 1949, Academic Press, Inc., New York, N. Y., pp. 47-115.
6. TANNER, F. W. *The Microbiology of Foods*. 2d Ed., 1944, Garrard Press, Champaign, Ill., 1196 pp.
7. WYNNE, E. S., AND FOSTER, J. W. Physiological studies on spore germination with special reference to *Clostridium botulinum*. I. Development of quantitative method. *J. Bact.*, **55**, 61 (1948).

Flavor of Summer, Fall, and Winter Varieties of Apples Baked in Pies

MARGARET H. STIRTON AND CLAUDE H. HILLS
Eastern Regional Research Laboratory, Philadelphia 18, Pennsylvania*

(Received for publication, May 9, 1950)

For pies, the flavor of summer varieties of apples was equal to or slightly superior to the flavor of fall and winter varieties. Calcium chloride, used to firm the softer varieties, did not affect their flavor.

The purpose of this study was to compare the flavor of summer, early fall, and winter varieties of apples when canned or frozen, and subsequently baked in pies. Calcium chloride was used to firm the softer varieties and maintain the desired texture during baking.

The use of calcium salts to improve the firmness of cooked apple slices *(1, 3, 4, 5, 6, 9)* has made possible the utilization of many summer varieties which would otherwise be too soft for canning or freezing. It is generally recognized that summer varieties of apples are rather tart and flavorful when used in home recipes *(1, 2, 8)*. Their principal deficiency from a commercial processing standpoint is a tendency to become mushy when cooked. This deficiency may now be corrected by the application of dilute solutions of calcium salts.

Materials and Methods

Apples were purchased from a nearby commercial orchard as the different varieties were harvested. The fruit was allowed to ripen at room temperature until the pressure readings, as measured by a Magness-Taylor *(7)* instrument, corresponded to values given by Pfund *(8)* for optimum maturity of New York State apples. When properly ripened, the apples were placed in storage at 35° F. (1.5° C.) until used.

Green and overripe apples and those measuring less than 2 inches (5.1 cm.) in diameter were sorted out before the samples were taken for canning or freezing. All apples were peeled, cored, sliced in eighths or twelfths, depending on the size, and held in 1% NaCl until used. This holding time was limited to a minimum to prevent water-logging of the slices. The optimum amount of calcium chloride to be used with the softer varieties was determined in a preliminary test by the methods described in a previous publication *(4)*.

For each canned sample, 450 gms. of apple slices were immersed in water or calcium chloride solution in a vacuum desiccator and held under 24-26 inches (61-66 cm.) of vacuum for 5 minutes to remove the air from the slices and to impregnate them with the solution. The slices were then heated to 190° F. (88° C.) in a minimum of tap water, drained, and packed into No. 2 lacquered cans containing 2 ounces (56.5 g.) of 50% sugar sirup. The cans were sealed, processed in a boiling water bath for 10 minutes, cooled to room temperature, and stored at 35° F. (1.5° C.).

Slices to be preserved by freezing were steam blanched for the minimum time required to prevent discoloration, 90 seconds in most instances, cooled in water or calcium chloride solution for 5 minutes, drained, and packed in cellophane bags with sugar. In 1947 the ratio of apples to sugar was 3:1; in 1948 it was either 9:1 or 5:1, depending on the acidity of the variety. The bags were sealed by heat, placed in boxes, and stored at —20° F. (—29° C.).

Preparation and Use of a Standard

The Baldwin variety was used as a standard reference sample because it is one of the better varieties for pies. A frozen sample was prepared for use with frozen slices, and a canned sample for comparing canned slices. Separate standards were prepared for use with the 1947 and 1948 lots of fruit. These standards were first scored by the taste panel, then used in each test at the previously determined score.

Procedure for Baking Apple Pies

Canned slices were held overnight at room temperature; the frozen slices were held overnight in the refrigerator at 35° F. (1.5° C.), then at room temperature for about an hour. All liquid was drained off both frozen and canned slices before the pie crust was filled, and 30-40 gm. of sugar was sprinkled over them. All spices were omitted to avoid masking the apple flavor. A top crust, in which were several holes, was placed on each pie. Four pies were placed on the shelves of a revolving oven preheated to 425° F. (218° C.). The pies were baked for 45 minutes at 425° F. (218° C.), then cooled for 2 to 4 hours. After the top crust was removed, the slices were scored for flavor.

Scoring of Apple Pies

A panel of 20 persons judged the pies in 1947, and 12 in 1948. Four to six pies were judged at each session. One pie in each group was prepared from the Baldwin standard. The panel rated for flavor on a scale of 10 to 1, 10 being best. The score assigned to the Baldwin standard (7 or 6) was the whole integer closest to the average flavor score, as determined in a preliminary test.

Discussion of Results

Table 1 shows the flavor scores for the 1947 samples. The varieties are grouped according to their harvest season in Pennsylvania. The data were analyzed statistically. The average standard error of all groups was used rather than the standard errors of specific group averages. On this basis, a difference of 1.1 between groups was significant (5% level) and a difference of 0.65 was slightly significant (20% level). Although

* One of the laboratories of the Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, United States Department of Agriculture.

TABLE 1

Flavor Scores of Pies Prepared from Canned and Frozen Apple Slices in 1947

Group	Variety	Frozen [b]		Canned [b]	
		Control	$CaCl_2$ treated	Control	$CaCl_2$ treated
Summer	Yellow Transparent	7.6	7.5	6.5	5.9
	Williams	5.9	6.6	6.8	6.9
	Rambo	6.1	6.8	6.7	6.4
	Gravenstein [c]	6.9	6.1	7.1	6.5
	Gravenstein [c]	....	....	7.3	7.2
	Ave.	6.63 ± .39 [d]	6.75 ± .29	6.88 ± .14	6.58 ± .22
Fall	Wealthy	5.2	6.0	5.8	6.4
	McIntosh	5.9	6.3	6.5	....
	Grimes [c]	6.1	....	6.7	5.3
	Grimes [c]	5.2	5.4	4.5	4.4
	Jonathan	6.3	....	7.2	....
	Red Delicious	5.3	5.6	5.5	5.2
	Ave.	5.67 ± .18	5.83 ± .20	6.03 ± .40	5.33 ± .41
Winter	Golden Delicious	5.1		4.8	
	Stayman Winesap	6.2	6.5	7.6	7.4
	York Imperial	6.8		5.6	
	Stark	6.4		4.7	
	Baldwin [e]	7.0		7.0	
	Ave.	6.30 ± .33		5.94 ± .58	
	Ave. of varieties treated with $CaCl_2$	6.03 ± .27	6.31 ± .21	6.45 ± .30	6.16 ± .30

[b] It is not possible to compare scores of canned samples with those of frozen samples because different standards were used for each.
[c] Represents two lots of fruit of the same variety.
[d] ± values = standard error of mean.
[e] Baldwin used as a standard of comparison.
Ave. Difference required for significance (P = .05) between varieties = 1.1; between groups = 1.1.

the summer varieties as a group scored consistently higher in flavor than the other groups, the difference in average score was significant (>1.1) in only one instance (canned, calcium treated). This difference was probably exaggerated by the omission of two varieties not requiring calcium. The difference between the summer and winter varieties (frozen) was not significant. It was not possible to compare scores of canned samples with those of frozen samples because different standards were used for each. The average scores of the calcium-treated samples and the corresponding controls showed no true difference.

The flavor scores for 1948 (Table 2) showed much smaller differences between groups, none of the differences being significant. Again the summer varieties (frozen) had the highest scores. Among the canned samples, the group averages were nearly identical. The calcium treatment did not affect the flavor of either the frozen or the canned slices.

There was considerable variation in the scores of the individual varieties from season to season. This may have been a seasonal effect, a sampling variation, or both. The four summer varieties had high scores both seasons. Gravenstein and Yellow Transparent were the best of this group. Of the fall varieties, Jonathan and McIntosh were the best and Red Delicious the poorest. In the winter group Baldwin and Stayman winesap were good, and Stark and Golden Delicious were poor.

The maturity of the apples when picked has a marked effect on flavor. This is especially true of the winter varieties which are often picked rather immature to

TABLE 2

Flavor Scores of Pies Prepared from Canned and Frozen Apple Slices in 1948

Group	Variety	Frozen [f]		Canned [f]	
		Control	$CaCl_2$ treated	Control	$CaCl_2$ treated
Summer	Yellow Transparent	6.3	6.3	5.0	5.0
	Williams	6.0	6.9	5.4	5.7
	Rambo	6.5	6.8	5.5	5.4
	Gravenstein	6.6	6.3	5.6	5.7
	Ave.	6.35 ± .13 [g]	6.58 ± .16	5.38 ± .13	5.45 ± .20
Fall	Dutchess	6.3	5.5	4.4	4.9
	Wealthy	6.8	5.2	5.7	6.1
	McIntosh	6.4	6.9	5.4	5.9
	Grimes	4.7	5.0	5.9	5.5
	Jonathan	6.7	....	5.6	....
	Red Delicious	....	....	4.7	5.1
	Ave.	6.18 ± .38	5.65 ± .43	5.28 ± .24	5.50 ± .33
Winter	Golden Delicious	5.6	6.3	5.1	5.0
	Stayman Winesap	6.9		6.2	
	York Imperial	5.4		6.3	
	Stark	4.9		5.1	
	Baldwin [h]	7.0		6.0	
	Ave.	5.96 ± .40		5.74 ± .27	
	Ave. of 10 varieties treated with $CaCl_2$	6.13 ± .19	6.13 ± .22	5.27 ± .15	5.43 ± .13

[f] It is not possible to compare scores of canned samples with those of frozen samples because different standards were used for each.
[g] ± values = standard error of mean.
[h] Baldwin used as a standard of comparison.
Ave. Difference required for significance (P = .05) between varieties = 1.1; between groups = 0.9.

lengthen their storage life. The Golden Delicious apples used in this study were rather immature when picked.

The most important facts brought out in this study were the high flavor scores of pies baked from summer varieties of apples. The use of calcium chloride to firm these varieties did not affect the flavor.

Summary

Fifteen varieties of summer, fall, and winter apples were preserved by canning or freezing and scored for flavor when baked into pies. The softer varieties were treated with appropriate amounts of calcium chloride to preserve their texture.

Results of two seasons' tests show that the summer varieties of apples were equal or superior to the winter and fall varieties for pies. Calcium chloride, necessary to firm the softer varieties, did not affect the flavor.

Acknowledgments

The authors wish to thank Dr. James Oyler, Knouse Foods Cooperative, Inc., Peach Glen, Pennsylvania, for suggesting this study. We also wish to thank Leah F. Bowman and Evelyn K. Chatterton for assisting in preparing the samples, W. E. Graham of Crown Can Company, Philadelphia, Pennsylvania, for supplying the cans for this work, and C. R. Eddy for his helpful suggestions regarding the statistical analysis of the flavor scores. We are also grateful to the members of the taste panel for their cooperation in scoring.

LITERATURE CITED

1. Anon. Firmed apple slices promise better pies and new market for early varieties. *Fruit Prod. J.*, **26**, 247 (1947).
2. Child, Alice M., and Brand, Ruth. Culinary quality of apple varieties grown in Minnesota. Minn. Agr. Expt. Sta. *Tech. Bull.* **128**, 23 pp. (1938).
3. Esselen, Jr., W. B., Hart, W. J., and Fellers, C. R. Further studies on the use of calcium chloride to maintain firmness in canned and frozen apples. *Fruit Prod. J.*, **27**, 8 (1947).
4. Hills, Claude H., Nevin, Charles S., and Heller, Margaret. Firming apple slices. *Fruit Prod. J.*, **26**, 356 (1947).
5. Holgate, K., and Kertesz, Z. I. The comparative usefulness of various calcium salts in the firming of canned and frozen sliced apples. *Fruit Prod. J.*, **28**, 37 (1948).
6. Kertesz, Z. I. The effect of calcium on plant tissues. *The Canner*, **88**, 26 (1939).
7. Magness, J. R., and Taylor, George F. An improved type of pressure tester for the determination of fruit maturity. U. S. Dept Agr., Dept. *Circ.* **350**, 1 (1925).
8. Pfund, Marion C. The culinary quality of apples as determined by the use of New York state varieties. Cornell University Agr. Expt. Sta. *Memoir* **225**, 73 pp. (1939).
9. Powers, J. J., and Esselen, Jr., W. B. The use of calcium salts in freezing McIntosh apples. *Fruit Prod. J.*, **25**, 200 (1946).

New York State Grapes Used in Making Champagne[a]

J. T. CUSICK

The Pleasant Valley Wine Company, Rheims, Hammondsport, New York

(REVIEW PAPER)

There are several varieties of grapes grown in New York State that are used in various percentages for making champagne. All are more or less high in acid content and all have good flavor. These are compared chemically and organoleptically with the one type of grape used for making champagne in France — and the grapes grown in California used for the same purpose.

A bottle of champagne is only a bottle of still wine impregnated with carbon dioxide. The method in which this self-developed carbon dioxide produced pressure in a closed bottle of wine was discovered in about 1698. At that time a Benedictine monk by name Dom Perigon *(5)*, is reported to have discovered the method of making champagne—the name champagne taken from the French territory in which the discovery was made. Perigon noticed that fermentation took place in wine in closed containers where any amount of sugar was present. Undoubtedly fermenation in various forms in closed or open containers was noted before Perigon's time, but he developed technique for controlling this fermentation. While today fermentation by yeast is used to a great extent and its action controlled for the production of many desirable products, still fermentation takes place sometimes in products when its occurrence is not the least bit appreciated. But it was Dom Perigon who adjusted and controlled the fermentation of wine in corked bottles. He did this by using a measured amount of wine and a weighed amount of sugar plus some yeast, and after fermenting the mixture in a closed bottle, found after a certain period of time, that considerable pressure was produced within the bottle which gave much effervescence to the wine when the bottle was opened.

In general this is the same method for making champagne today. The main difference consists in clarifying a fully fermented wine, placing this wine in a bottle for a secondary fermentation, then adding a little sugar and yeast. When this secondary fermentation is completed in the closed bottle, the bottle is placed up-side down in a rack and the sediment collected on the surface of the cork in the neck of the bottle. In this position the necks of the bottles are placed in a freezing mixture. After a few minutes a plug of ice about one-half inch in height is formed from the wine directly in contact with the sediment and cork. Then when the bottle is placed upright and the cork loosened, pressure from within blows the cork and plug of ice from the bottle, carrying

[a] Paper presented at the Spring Meeting of the Western New York Section of Institute of Food Technologists, Rochester, New York, April 30, 1949.

the sediment along with it. A quick temporary closing of the bottle is made, and later a small amount of sugar syrup is added—under pressure. A new cork is inserted and secured by a wire. The champagne is now ready for market. Anyone interested in a more detailed account of making champagne is referred to Manufacture of Champagne and Burgundy by Champlin, Goresline and Tressler *(2)*.

Real champagne is made this way. The contents of the bottle may have a pressure from 1 to 5 or 6 atmospheres or from 15 to approximately 90 pounds to the square inch at 15 degrees centigrade. To develop 90 pounds of pressure in a 26 ounce bottle, this is the usual pressure, requires 20 grams of fermentable sugar. The wine used is a dry white wine, of good flavor, light straw in color, and having an alcoholic content of about 11% before starting this secondary fermentation. After the secondary fermentation is completed, the alcohol is about 12½%. The yeast used is an agglomerating yeast of the Saccharomyces ellipsoideus type.

A blend of wine for use in making champagne should have an acid content, as tartaric, of about .6 of 1% or more. The wine plus the yeast culture and sugar is called a cuvee.

Every winery has its own technique in the preparation and development of yeast used in fermenting wines. Also every winery has its own special brands of wine made from its own selection of grapes. These grapes are purchased on a percentage variety basis. This is done in order to have blends of wine for making champagne, uniform from year to year.

The varieties of grapes grown in N. Y. State that are used in making wine and champagne are: Elvira, Delaware, Catawba, Isabella, Niagara, Dutchess, Norton, Clinton, Ives, Concord, and numerous other lesser varieties or combinations of other varieties in small amounts. Clinton, Ives and Concord are used mostly in sparkling Burgundy.

All the above varieties maintain their individual characteristic quality from year to year. The difference in the pressings from any particular variety being mostly in a variation in the sugar and acid content variation from year to year even when the fruit is perfectly ripe. There is, however, a certain somewhat definite ratio of sugar to acid characteristic to each variety. This gives the sugar-acid taste. Aside from the sugar-acid taste, each variety has its own distinct and distinguishing flavor and aroma—call it bouquet if you wish. The combination of the proper sugar-acid balance coupled with a pleasing flavor and aroma is the basis of good wine.

While most of the N, Y. State varieties of grapes mature perfectly it may be that sometimes as in the case of the Catawba—which mature very late in the growing season—climatic conditions may interfere with its perfect ripening, and perhaps only a part of crop of this variety can be used. Yet there is an abundance of other varieties still remaining, the quality of the pressings from which are most suitable for making wine and champagne. Rarely is it necessary to eliminate any appreciable amount of pressings from any variety from the cuvee mixture. In other words in N. Y. State the blend of wines for champagne is not dependent on any one or two varieties of grapes, since there are many varieties of fine flavored grapes available any season. Hence N. Y. State champagne has excellent vintage, for its production any year.

In France the small black Pinot grape and a few white Pinot and white Chardonnay are crushed to make the French champagnes. If the black Pinot grape—which is used almost exclusively—comes to maturity under the most favorable weather conditions and the wines from same have a "mellow" flavor it is called a vintage year. However, the French do not have recourse to any other variety or varieties of grapes should the cuvee from the black Pinot not be of prime quality. The French do, however, overcome much of this difficulty by making blends of cuvee from several districts and also blending various seasons' pressings.

The Pinot grape pressings or must is deficient in sugar or does not contain enough sugar necessary for making wine sufficiently high in alcohol for a champagne mix. But the percentage of titratable acid, as a rule, is ideal. The grapes are usually high in flavor, and pleasant to the taste. While the French grapes average about .85 of 1% acid as tartaric, the grapes in N. Y. State average slightly higher than the French in acid in most varieties. Elvira and Catawba grapes are very high in acid content. Also some N. Y. State grapes are comparable to the French type grape in that they are deficient in sugar, or they require the addition of sugar to the must for developing the proper % of alcohol for champagne making. On the whole, though, the chemical analyses and the aroma and flavor of the French and N. Y. State grapes are very closely comparable.

California which has a grape tonnage twenty times that of N. Y. State produced as of 1948—about 4.8 million half-pint units of champagne. In the same period N. Y. State, with a tonnage 5% that of California produced more champagne than California or about 10 million half-pint units. Table 1 shows these figures.

TABLE 1

Production of Champagne for Year Ending October 1, 1948—By States

Time	Bottle Fermented		Bulk Process	
	California	New York	California	New York
October, 1947, through June, 1948	1,044,882	6,260,069	2,008,650	1,435,760
July, 1948	95,992	575,762	339,268	81,556
August, 1948	176,292	1,299,846	532,132	78,154
September, 1948	275,788	463,360	338,406	107,142
Total for 12 months	1,592,960	8,599,037	3,218,456	1,702,612

The above figures represent the production of all sizes of champagne calculated as half-pint units *(1)*.

The grapes used in California for champagne making are some Pinot and some white Chardonnay—the same varieties as used in France—but these varieties as grown do not give an appreciable tonnage. Hence numerous other varieties are pressed out for champagnes. The acid (tartaric) content of the fully ripened California grapes, generally, is often too low or insufficient in amount for making good champagne. Also the sugar content is too high for same. To provide sufficient

acid in the must, the California grapes are picked in an unripened state or citric or tartaric acids are added to the cuvee. And only a few varieties of California grapes are used for champagne because many varieties are either neutral or weak in flavor or are undesirable in the champagne mix. According to Dr. W. V. Cruess, of the University of California, College of Agriculture, in his book on *The Principles and Practices of Wine Making (4)*, in comparing the flavor of grapes grown in N. Y. State with those grown in California, he states, "The Muscat type grape is the only grape grown in California that possesses an aroma in intensity equal to that of Eastern United States native American varieties." Some wineries in California are experimenting with eastern varieties but tests on pressings from these would indicate that the growers have not been able to reproduce the quality product of these same varieties as grown in N. Y. State. However, a small percentage of California wine is sometimes used in N. Y. State champagne mixes to reduce the acidity in New York State champagne mixes to an average acid content as tartaric of approximately 0.70%.

Typical acid-sugar ratios of grape pressings from some varieties grown in France and in California and also several varieties from N. Y. State are listed in Table 2.

It is unnecessary to state that alcohol is the principal item of interest in fermented beverages *(3)*. And since the aroma and flavor of alcohol is not especially pleasant, strong flavors are needed to counteract these objectionable features in order to give a pleasant taste and good aroma to the wine. As stated before, an abundance of aroma and flavor, pleasing to the taste and smell is characteristic of N. Y. State grapes. Therefore these flavors which carry into the fermented product to a marked degree, have a tendency to mask the flavor and pungency of the alcohol. Again high acid gives sharpness or acid taste to a product and high acid predominates in N. Y. State grapes. Conversely a wine low in acid has a flat or neutral taste. All this adds up to a properly balanced beverage from the standpoint of flavor. Beverages depend upon a particular pH value and also on a particular total or reserve acidity if they are to have a correct and lasting flavor. The pH value of most N. Y. State grapes is high enough to warrant a lasting flavor and their characteristic aroma and flavor intense enough to give a pleasing taste.

Summary: The grapes grown in N. Y. State that are used in the making of champagne compare in their chemical analyses very closely with those grown in France and used in making champagne in that country. The intensity of the aromas and flavors are equally comparable. However, it is to be said also, that because of the numerous varieties available, and suitable for making champagne, N. Y. State wine makers are not dependent on the so called "vintage year" for a quality product.

LITERATURE CITED

1. Anonymous. *Report of Bottle Fermented Champagne Producers Inc.*, 901 Barr Bldg., Washington, D. C. Nov. 1948. Table 1.
2. Champlin, F. M. Goresline, H. E., and Tressler, D. K. Manufacture of champagne and sparkling burgundy. *Ind. and Eng. Chem.*, **27**, 1240 (1935).
3. Crocker, E. C. Flavor, 1st Ed. 1945. McGraw-Hill Book Co. Inc., New York.
4. Cruess, W. V. *The Principles and Practices of Wine Making*, 2nd Ed. (1947). The Avi Publishing Company, Inc., New York.
5. Vizetelly, Henry. *A History of Champagne* (1882). Scribner & Welford, New York.

TABLE 2

Sugar-Acid Ratio for Grapes from Various Localities

Date	Location	Type	Balling average	% Acid (Tart.)	pH	Sugar-Acid Ratio
1935 *(4)*	California	40 Varieties, 240 Samples	22.1	.61	....	1:36
1936 *(4)*	California	40 Varieties, 240 Samples	23.0	.50	....	....
1948	California	Burger	19.5	.55	3.8	1:36
1948	California	Green Hung	20.5	.52	3.7	1:39
	France	Black Pinot	18.5 av.	.90 av.	....	1:20
1946	New York	Delaware	19.0	.93	3.2	1:20
1947	New York	Delaware	20.4	1.05	3.2	1:20
1948	New York	Delaware	18.6	.87	3.2	1:21
1947	New York	Elvira	13.4	1.09	3.0	1:12
1948	New York	Elvira	15.3	1.22	3.0	1:12
1947	New York	Catawba	16.1	1.24	2.9	1:13
1948	New York	Catawba	18.6	1.35	2.9	1:14
1948	New York	Niagara	17.4	.75	3.2	1:20
1948	New York	Concord	17.0	1.20	3.1	1:14

Industrial and Legal Viewpoints

Recent Advances in Air Transportation of Perishable Foods[a]

J. PRESCOTT BLOUNT
Mill Valley, California

(Received for publication, August 8, 1949)

Economic and operational aspects of transporting perishable cargoes by air are discussed. The future possibilities for the packing and distribution of this type of products is developed.

After six years of pioneering, we are only now able to say that perishable foods have a place of commercial importance in today's freight planes. Much remains to be done in the fields of refrigeration and distribution before perishable foods become a leading source of air-freight tonnage.

While the idea long intrigued many people, the first sustained effort to move food in large volume by air came in 1943. Ralph Myers, a vegetable shipper from Salinas, California, did much to rouse the produce industry by advertising, talking, and making trial shipments. In the same year, Reuben Rath, of the Rath Packing Company, Waterloo, Iowa, actually proposed to United Air Lines that they have a special cargo plane built, partly at Rath expense, for shipping fresh pork from Iowa to the West Coast. Surveys were made by United but little could be done at that time due to War restrictions on cargo space.

Interest in this subject increased in 1944, with an important joint research project being undertaken by United Air Lines, Wayne University, and the Atlantic & Pacific Tea Company. Later, this effort was supported by Goodyear Tire and Rubber Company's Pliofilm Division, and by the Hinde and Dauch Paper Company, of Sandusky, Ohio. American Airlines inaugurated the Nation's first airfreight service by flying a plane-load of pre-packaged spinach from Los Angeles to Cincinnati, on September 15, 1944.

The U. S. Department of Agriculture deserves much credit for having taken note of these first efforts, and for having foreseen the far reaching effects this new form of transportation might have on the packaging and marketing of highly perishable fresh fruits and vegetables. Under Dr. F. L. Thomsen, Chief, Division of Marketing and Transportation Research, several very interesting studies were completed, covering strawberries, tomatoes, lettuce and other products.

While these studies were being made in 1944 and 1945, Ralph Myers increased his experimental shipping program, moving 365,000 pounds of fresh fruits and vegetables during this period. His report, "Air Freight for Fresh Fruits and Vegetables," contains many observations and suggestions which in the light of recent experience have proven acurate guides to successful operation. The following is quoted as being particularly applicable:

Page 14, " . . . Shipments of perishables by air freight must be handled, packaged, and distributed by men and organizations experienced in and fully qualified to handle fresh fruits and vegetables."

Under the subject, "Receiving Market Distribution," page 15, he says, "No particular type of receiver or dealer appears better qualified or equipped to handle airborne perishables than any other type. But all receiving market operators—whether receivers, jobbers, wholesalers or retailers—who elect to deal in airborne perishables, must be prepared to protect all of the contents of each shipment from the moment it arrives until ultimate purchase."

Under "Arrival Condition," he says, "Speaking commercial—and almost literally—all fresh fruits and vegetables shipped in these experiments, and probably most or all others, can be harvested at the ideal stage of maturity for maximum taste, color, flavor and appearance, and through the medium of air freight be delivered to consumers from any point to any other point in the United States in practically the same condition, without loss, spoilage or waste.

"This conclusion, quite obviously, is based upon the condition that preparation, shipping and handling be carried out as outlined in other phases of this report.

"Consumer Acceptance. All other findings and conclusions in this report are but corollary to the factor of consumer acceptance. We have found that facilities are available for air transport of our products. We have found that airborne fresh fruits and vegetables, properly handled and packaged, earn imediate consumer preference on the grounds of better appearance, quality, taste and flavor.

"The final question now evolves: 'How much premium will the consumer pay, day in and day out, for airborne products, and is it possible to deliver them to her within the range of that premium?' Our studied conclusions are:

"1. Given opportunity to obtain airborne merchandise in her daily purchases, the average consumer—except in extremely low income groups—would gladly and without show of sales resistance, consistently pay an overall premium averaging 10c a pound over prices paid for merchandise available to her through other forms of transportation.

[a] Presented before the Ninth Annual I. F. T. Convention, San Francisco, California, July 12, 1949.

"2. Shipments of our perishables on any appreciable scale, within the near future, will be determined by whether the cost of delivering airborne merchandise, including the extra cost of pre-packaging, can be held within the limits of this 10c per pound overall average premium.

"3. If this is possible, and we believe it is, the average consumer, with educational and merchandising efforts directed to assist her in appreciating the superior qualities of airborne fresh fruits and vegetables, will have regularly available an article never before attainable to her, and the produce industry will in short time experience a marked stimulus in the overall consumption of its products."

Since this report was issued in the fall of 1945, there has been a constant struggle, primarily by airlines anxious to develop airfreight, to apply the formula which would make of this type of business, a regular and large scale user of its service.

No one can deny that entry of the all-freight airlines, such as Slick and the Flying Tigers, did much to stimulate this movement. Along with the post war all-freight lines, came young men who sought a future as specialists in the shipping, or in the marketing of airborne foods. Bud Crowl, of the Sped Fresh Company, Dayton, Ohio, is an example. He specialized in fresh fruits and vegetables, but failing to find adequate sources of supply, he turned to the handling of airborne flowers, while waiting for more food shippers to enter the picture.

Other examples are Hardy Carter, of Skyborne Seafoods, Chicago, who handled Eastern lobsters. Glen Martin's Glenmar Farms of Chestertown, Maryland, pre-packaged large quantities of its own vegetables plus additional supplies flown from distant areas. Lee Slayton of Airfoods, Inc. of Toledo, Ohio, established sales outlets, but suffered through lack of sources of properly packaged foods of "airborne" quality and maturity. I. Townsend Burden of New York City, organized the firm of Burden & Weaver, and for a year and a half, has been handling increasingly large quantities of fresh dungeness crab and crab meat, by air freight from San Francisco.

1948 brought several important contributions to the perishable foods-by-air crusade:

1. A new shrimp fishing area was discovered near Carmen, Campechi State, Mexico. The airfreighter was for some time the first, and only means of bringing these shrimp fresh to U. S. markets. While refrigerated boats are now being used to some extent, the airfreighters are still hauling fresh shrimp to Brownsville, Texas.

2. With Governor Earl Warren's personal interest behind it, the newly formed California Aeronautics Commission sponsored the formation of, "The Air Cargo Institute of California." This organization's membership included all major airlines interested in the development of air freight, with emphasis on perishables. Manufacturers of planes, containers, packaging materials, and supply and service organizations were also members, as were shippers of perishables, and specialists from the State and Federal Department of Agriculture, and College of Agriculture. It seemed an ideal team of mutually interested persons and organizations, well qualified to sponsor tests of containers, refrigeration, marketing and every phase that had to do with placing perishable foods in the air on a regular and profitable basis.

The Institute, however, was inadequately financed to undertake the full scope of work intended for it, and remains in a dormant state today, perhaps waiting only for some new event to sweep the air freight development idea up another step.

3. In the fall of 1948, and under the name of the Air Cargo Institute, Lockheed Aircraft Corp. provided engineers and facilities, and the U. S. Department of Agriculture, Bureau of Plant Industry, provided products and trained physiologoists. They tested 34 varieties of fresh fruits and vegetables to determine the effects of altitude, and of rate of change in pressure, on each commodity. The results were presented in a report dated February 15, 1949, and entitled "Altitude Tests of Fruits and Vegetables." In brief, these tests tend to prove, contrary to general belief, that nearly all produce of this type, can stand any altitude which we expect to fly with little or no effect. However, an important exception is the case of soft centered candies. High quality bon bons actually cannot be successfully shipped by air in unpressurized cabins due to splitting and leaking caused by air pressure changes. The next project, and one which is badly needed, is to test the effects of temperature, and its rate of change and duration, on this same group of commodities. Work of this type will doubtless continue, and its results will guide airline managements and manufacturers of cargo planes in providing the type of service and equipment which is best designed to serve shippers and distributors of perishable airborne foods.

Conclusions

1. During the last six years we have seen perishable foods which began as sheer experiment, in the air transport field, move to a position of commercial importance today, with literally millions of pounds being flown by air this year.

2. We have found that perishable foods will move by air if one or more of the following factors are present:

A. Quality of the airborne product is recognizably superior when it reaches the consumer.

B. Savings in container weight, and weight of portions which would have spoiled, or would have been discarded if moved by conventional transport, amount to enough to compensate for additional per pound cost of air freight.

C. Cost of production is low enough in relation to market price to justify air freight cost. (Example: the Mexican operation).

D. The product is too perishable to move to market by other means than air.

E. Short term fluctuations in market price due to shortages, which afford opportunity of capitalizing on the price spread.